BALTIMORE-WASHINGTON RAPID RAIL

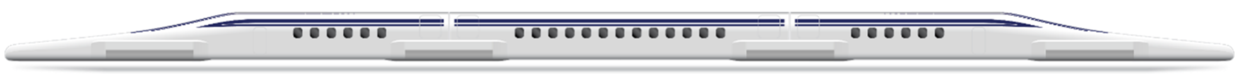

Exhibit N

GZ 4.3 Prelim Geotech Eng Assessment Report 19.03.18 Final

Baltimore-Washington SCMAGLEV Project Preliminary Geotechnical Engineering Assessment Report

Task: 4.3 Preliminary Engineering
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EXECUTIVE SUMMARY

The Northeast MAGLEV (TNEM) and Baltimore-Washington Rapid Rail (BWRR) are proposing a 60 km (37 mile) long superconducting magnetic levitation (SCMAGLEV) rail line between Washington, D.C. and Baltimore, MD. Two alignment alternatives are being considered and a preliminary ground investigation program was conducted in the spring-summer of 2018 to provide an initial assessment of anticipated ground conditions for construction. The program consisted of a total of 23 boreholes at approximately 3 km intervals along the alignment alternatives and was primarily performed by local Disadvantaged Business Enterprises (DBEs).

The results of the ground investigation program, summarized herein, confirm the entirety of the proposed alignment alternatives will be constructed within unconsolidated sediments of the Coastal Plain physiographic province. The material consists of Holocene-Pleistocene alluvium and terrace gravels, as well as Cretaceous sediments of the Potomac Group. The primary formations of the Potomac Group encountered are the Patuxent Formation, Arundel Formation, and Patapsco, which also represent important regional aquifers and aquicludes. The formations are fluvial in origin and consist of laterally discontinuous layers of sands, silts, and clays, with gravels. The Arundel Fm., primarily clays, acts as a barrier between the Patapsco and Patuxent aquifers. Pre-Cretaceous bedrock was encountered at depth at locations along the alignment in closest proximity to the Fall Line (boundary between the Piedmont and Coastal Plain physiographic provinces), corresponding to the Washington, D.C. and Baltimore Stations, as well as the central alignment segment. Limited temporary groundwater monitoring well installations suggest a fairly shallow groundwater table, indicating tunneling would occur almost entirely below the groundwater table.

The observed ground conditions permit preliminary considerations for design and construction, particularly with respect to top-down construction of stations, ventilation shafts, and Tunnel Boring Machine (TBM) tunnels. The high groundwater table and unconsolidated nature of the sediments impact the approach to support-of-excavation (SOE) for the top-down structures, with a need to prevent dewatering that could result in adverse impacts to existing structures by ground settlement. Tunneling is likely to be entirely within Potomac Group sediments and below the groundwater table. This indicates the need for a closed-face TBM capable of maintaining a pressurized face during excavation. The pressurized face prevents groundwater inflow, and hence dewatering of the sediments, minimizing both disturbance of the sediments as well as surface settlement.

The next phase of ground investigation will target the chosen alignment alternative with a higher quantity of boreholes and geotechnical material testing. This information, in additional to further illuminating the anticipated ground conditions along the alignment, will provide the data and ground parameters necessary for detailed design by the Design-Build (DB) contractors.

1.0 INTRODUCTION

The Northeast MAGLEV (TNEM) and Baltimore-Washington Rapid Rail (BWRR) are proposing a 37-mile (60 km) long superconducting magnetic levitation (SCMAGLEV) rail line between Washington, D.C. and Baltimore, MD. This Geotechnical Synopsis Report (GSR) summarizes the anticipated subsurface conditions during construction of the underground stations in Washington, D.C. and BWI Airport, the bored tunnels and cross-passages (if required), cut-and-cover tunnels, ventilation shafts, portal structures, viaduct structures, and the above-ground Baltimore Station. This report is intended to provide a general overview of soil/site conditions with the limited information collected during the preliminary ground investigation program. Additionally, preliminary discussions of construction considerations for major components of the alignment are discussed. The next phase of ground investigation, which will be far more extensive, will provide the testing data required for detailed design by the Design-Build (DB) contractors.

1.1 Purpose of Geotechnical Synopsis Report

This GSR is prepared for the Environmental Impact Statement. The objectives of the GSR are to:

1. Provide a preliminary evaluation of ground conditions, ground behavior, groundwater, in-ground obstructions, subsurface contamination, and gas conditions for the alignment.
2. Provide a summary of general construction considerations.
3. Provide a basis for preparing and executing the detailed ground investigation program along the preferred alignment alternative, including development of a Geotechnical Baseline Report (GBR).

1.2 Subsurface Investigations

The preliminary geotechnical boring program was executed by the local DBE Geotechnical firm BOTA Consulting Engineers, Inc. A total of twenty-three (23) borings were performed along the proposed alignment alternatives of the SCMAGLEV project (Figure 1). Prior to the start of drilling operation at each borehole, both Miss Utility and a Private Utility Locator were called to clear all underground utilities, notably electric line, gas line, waterline, sanitary sewer line, cable lines, communication lines, and others, within vicinity of the borehole. Where conflicts with utility lines were identified, the boreholes were offset to a safe distance before drilling operations began.

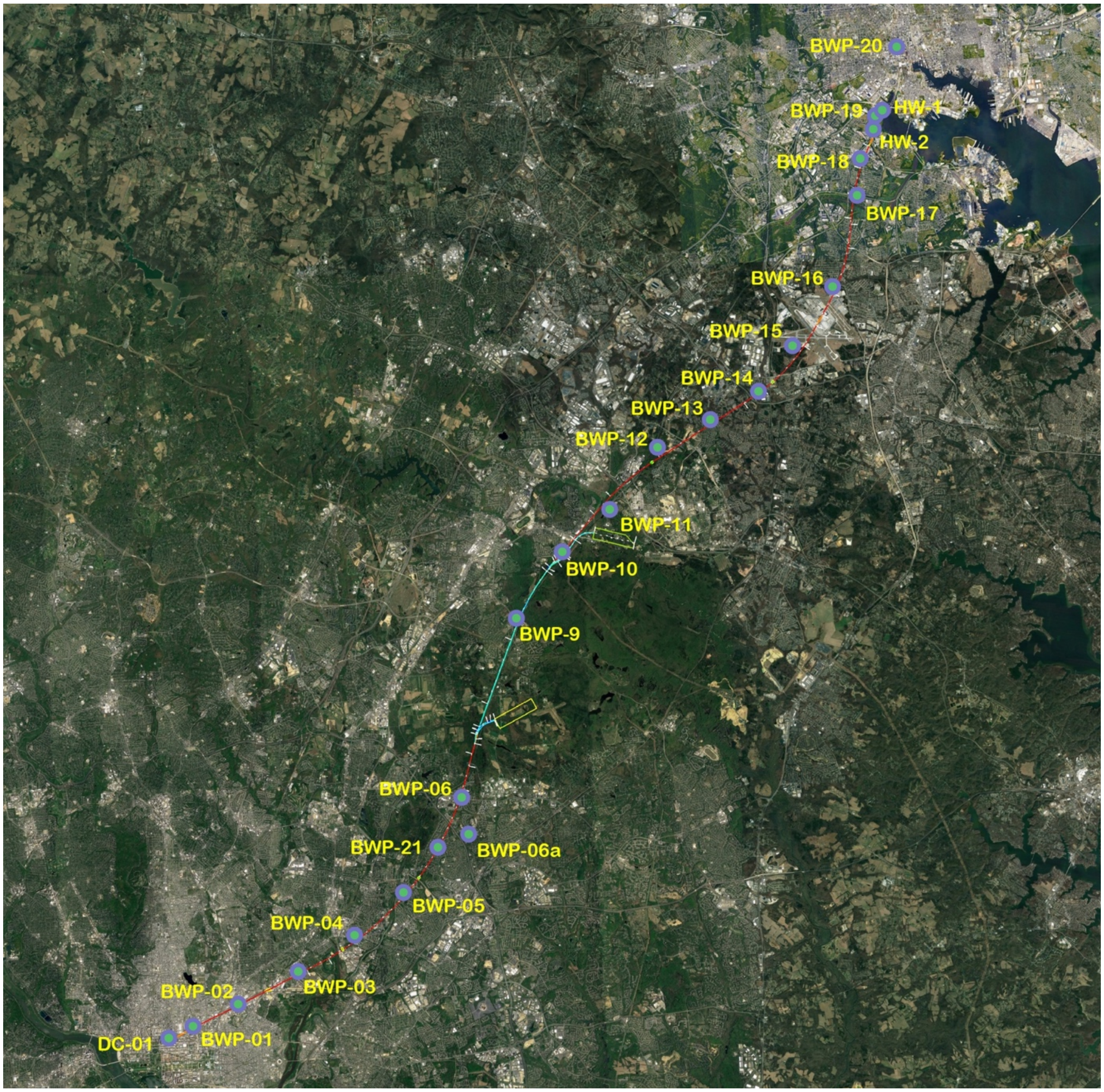


Figure 1. Plan view of boreholes from the Preliminary Ground Investigation Program

2.0 PROJECT DESCRIPTION

The SCMAGLEV Project is proposing a high-speed train system between Washington, D.C. and the City of Baltimore, approximately 60 km (37 mi) in length. This is the first leg of an envisioned route from Washington, D.C. to New York City. The SCMAGLEV system operates using a combination of electromagnetic levitation (support), propulsion and lateral guidance, rather than flanged wheels, axles and bearings as in conventional high-speed railways. The train system will cross several transportation corridors including interstate highways (I-95, I-195, MD295 Baltimore Washington Parkway, I-595, I-695, I-895), several state, city and local routes, and railroad lines, as well as the BWI Airport. All crossings will be grade separated. The project owner is the Northeast Maglev / Baltimore Washington Rapid Rail (TNEM / BWWR), with Louis Berger as the prime consultant and Gall Zeidler Consultants as the tunneling sub-consultant.

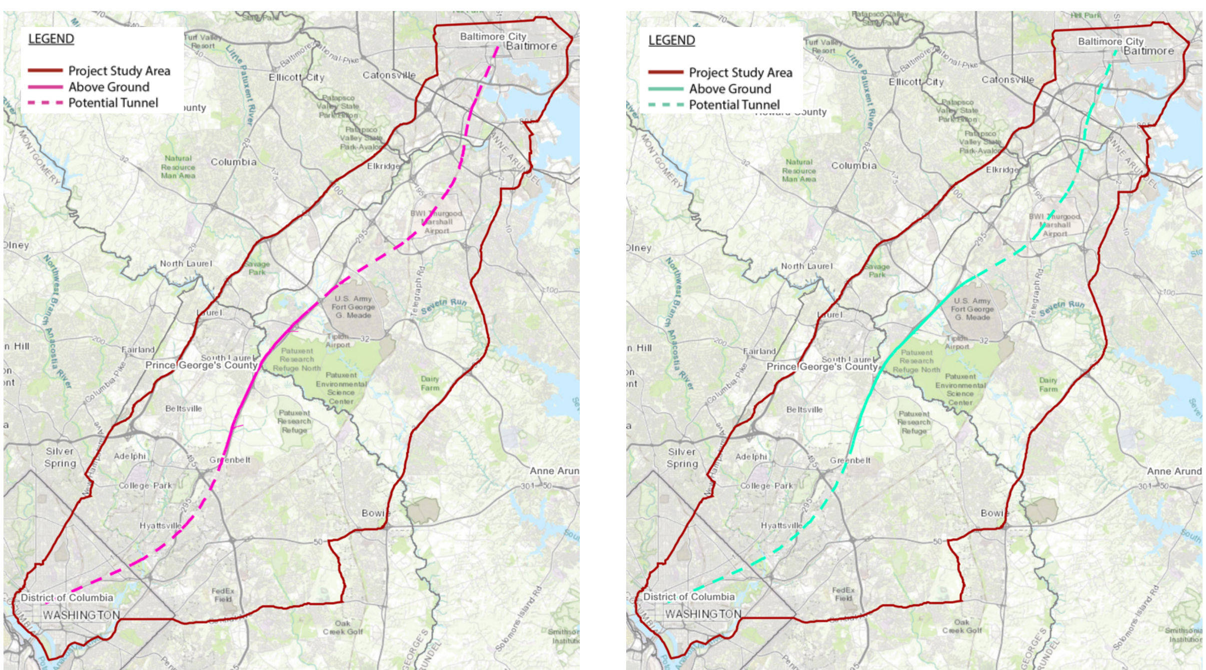
The project is in the preliminary engineering phase. An independent environmental review process was initiated in the fall of 2016 in accordance with the National Environmental Policy Act (NEPA), with a Record of Decision (ROD) anticipated in mid 2019.

2.1 Alignment Alternatives

The project is located in Washington, DC and Maryland, traversing a distance of approximately 60 km (37 mi) with three underground stations in Washington D.C., at BWI Airport and in Baltimore.

The SCMAGLEV system runs on an independent grade-separated right-of-way. The ultra-high speeds require relatively straight geometry with limited horizontal and vertical curvature. To accommodate the range of topographical and surface features, existing dense urban areas, utility mains, and existing structures, the proposed construction is expected to consist of below-ground (tunnel) for at over half of the route, and elevated structures (viaduct) for the remainder. The train system incorporates two main guideways, three stations, one rolling stock depot, electrical substations, right-of-way maintenance facilities, tunnel ventilation plants and emergency egress facilities.

The environmental review process initially identified several possible alignment alternatives which generally follow existing transportation corridors such as Baltimore Washington Parkway (MD 295), Amtrak Northeast Corridor, Washington, Baltimore and Annapolis Trail or a combination thereof, as shown in Figure 2. Alignment alternatives have since been further screened to two, which traverse the eastern and western sides of the BW Parkway. Overall, approximately 75% of the alignment is anticipated to be in tunnel and the remaining 25% is on elevated viaduct.



a) b)

Figure 2. a) Alignment alternative J Modified 1, and b) Alignment alternative J1 Option 5.

2.2 Elevation Datum

Elevations references in this report are reported in meters and based on the North America Vertical Datum of 1988 (NAVD88).

3.0 GEOLOGIC SETTING AND SUBSURFACE CONDITIONS

3.1 Regional Geological Setting

3.1.1 Washington, D.C.

A review of the published geological information indicates that the project rail alignment is geologically located in the Upland Deposits of the Atlantic Coastal Plain Physiographic Province. The Coastal Plain deposits are composed of sand, gravel, silt, and clay in well sorted and bedded fluvial deposits. The deposits are generally described as well-rounded cobbles and pebbles of gravel and quartz sand interbedded with layers of silt and highly plastic clay. Although the clay sediments appear to be very strong and over consolidated, these soils are unstable due to their inherent low residual shearing strength and the presence of fissures in their blocky structure. The clay and silt sediments are also known to be expansive and prone to shrink and swell due to the presence of montmorillonite as the predominant clay mineral.

3.1.2 City of Baltimore

The City of Baltimore lies within two physiographic provinces, the Piedmont Plateau and the Atlantic Coastal Plain. The North-Northeast trending Fall Line separates the two provinces, dividing the city in half. Most of the city is characterized by nearly level to gently rolling uplands, dissected by narrow stream valleys. The Baltimore segment of the proposed alignment alternatives, located in the eastern part of the city, is geologically situated entirely within the Atlantic Coastal Plain. Hilly areas and steep side slopes border the deeper stream valleys, particularly along the Fall Line, concentrating the flow of water in these watersheds into fast-moving, high-energy streams. Elevations range from sea level, where the Patapsco River is a tidal estuary, to as much as 146 m on the ridge on the Piedmont Plateau in the northwestern part of the city. These ridges descend gradually to the Coastal Plain in the south and east, where hilltop elevations average about 76 m.

City of Baltimore is underlain by the Baltimore Gneiss, a series of Pre-Cambrian quartzo-feldspathic, migmatite domes. Unconformably atop the bedrock are sediments of the Lower Cretaceous Potomac Group, which are overlain by younger sediments consisting primarily of sand and gravel and minor amounts of silt and dark clay.

3.2 Subsurface Materials Along Alignment Alternatives

The regional geology along the proposed alignments is dominated by unconsolidated sediments Holocene to Pleistocene in age, Cretaceous Potomac Group sediments, and bedrock. With the alignments situated East of the Fall line, construction activities will primarily fall within sediments of the Potomac Group, which includes the Patapsco Formation (Fm.), Arundel Fm., and Patuxent Fm. (Glaser, 1969). The results of the preliminary geotechnical investigation, discussed herein, provide insight to the general stratigraphy and geotechnical properties of materials along the proposed alignments.

3.2.1 Fill

Fill deposits in the project area are unconsolidated soils that have been deposited by the activities of man. These soils will be encountered at the ground surface at the shaft sites and in general over the entire land surface along the proposed alignment alternatives. Fill deposits are highly variable in extent and composition, including all types of locally derived soils. Fill ranges from fine-grained to coarse-grained material and can contain fragments of construction debris, including wood, concrete, metal, cinders, and trash in varying amounts depending upon location.

Fill is more frequently granular than fine-grained and will typically be saturated unless its elevation is above the normal range of groundwater levels. Perched groundwater conditions above normal piezometric levels due to trapping of surface water infiltration can exist in fine-grained Fill soils. Permeability of the Fill will vary significantly based on its specific composition.

3.2.2 Alluvium

Holocene alluvium occurs within and along the floodplains of fluvial bodies encountered along the proposed alignments. Pleistocene alluvium is present within Washington, D.C. and consists of loose to dense silty sands with gravels and stiff lean clays. Borings show the thickness of this unit between 24 and 28 meters.

3.2.3 Terrace Deposits

Terrace deposits consist of interbedded sand, gravel and silty-clay. These sediments are Pleistocene in age and are encountered adjacent to streams crossing the proposed alignment alternatives, particularly through Prince George's County.

3.2.4 Potomac Group

The Potomac soils were previously overlain by several hundred feet of soil deposits that were later eroded away. The fine-grained cohesive soils are hard and over-consolidated, and the coarse-grained cohesionless soils are dense to very dense. The primary formations that constitute the Potomac Group are the Patapsco/Arundel Fm. and the Patuxent Fm.

3.2.4.1 Patapsco Formation

The Cretaceous aged Patapsco Formation unconformably overlies the Arundel Fm. and consists of highly colored and variegated clays, sandy clays, and silts.

3.2.4.2 Arundel Clay

The Arundel Clay is a dense, low-permeability dark gray to maroon, massive lignitic clay and silt unit that also serves as the confining unit between the Lower Patapsco Aquifer system and the Patuxent Aquifer System. Identification is based mainly on the presence of dark grey clays and an overall higher proportion of clay and silt to sand compared with the Patuxent Fm. The Arundel Fm. unconformably overlies the Patuxent Fm. Borings show the thickness of this group (Patapsco Formation and Arundel Clay) between 13 and 86 meters.

3.2.4.3 Patuxent Formation

The Cretaceous-age Patuxent formation lies unconformably on the igneous and metamorphic bedrock along the proposed alignment alternatives. The Patuxent is comprised of permeable sand inter-bedded with low permeability silt and clay layers. The fluvio-deltaic deposits of the Patuxent are separated from the unweathered bedrock by an irregular saprolitic layer of varying thickness that reflects the undulating surface of the basement rock. Borings show the thickness of this formation between 6 and 54 meters.

3.3 Bedrock

The Maryland Coastal Plain physiographic province is underlain by basement rock consisting of Precambrian to Paleozoic crystalline rocks, as well as Mesozoic sedimentary and volcanic rocks. The overlying Cretaceous-age Potomac Group sediments often sit upon a saprolitic layer of weathered bedrock. Overall, the basement rock dips to the east-southeast at an approximate rate of about 13.26 m/km near the fall line, becomes gentler at approximately 5.68 m/km in southern Maryland, and increases in gradient to approximately 16.10 m/km thereafter (Hansen & Edwards, 1986). Locally, the bedrock surface is irregular. A general map of the elevation of the bedrock surface beneath the Coastal Plain sediments of Maryland is shown in Figure 3 below. This figure also includes an overlay of the approximate proposed alignment alternatives.

Bedrock shallows within 100 m of depth at segments of the proposed alignment alternatives that are closest to the Fall line, with an eastward deepening of bedrock at those segments that move easterly away from the Fall Line. Typically, a zone of weathered bedrock and saprolite of varying thickness was encountered in the upper part of the bedrock, with potential boulders of the bedrock material encountered in a Washington, D.C. borehole (DC-01). It is anticipated that the bedrock level will be at approximately -24 m El. in Washington, D.C., and about -22 m El. towards Baltimore. However, additional boreholes must be drilled to confirm these depths/elevations. This assessment is based on a limited number of borings and cannot account for local irregularities in the bedrock. A more constrained assessment of bedrock surface elevations will be determined from the next phase of ground investigations.

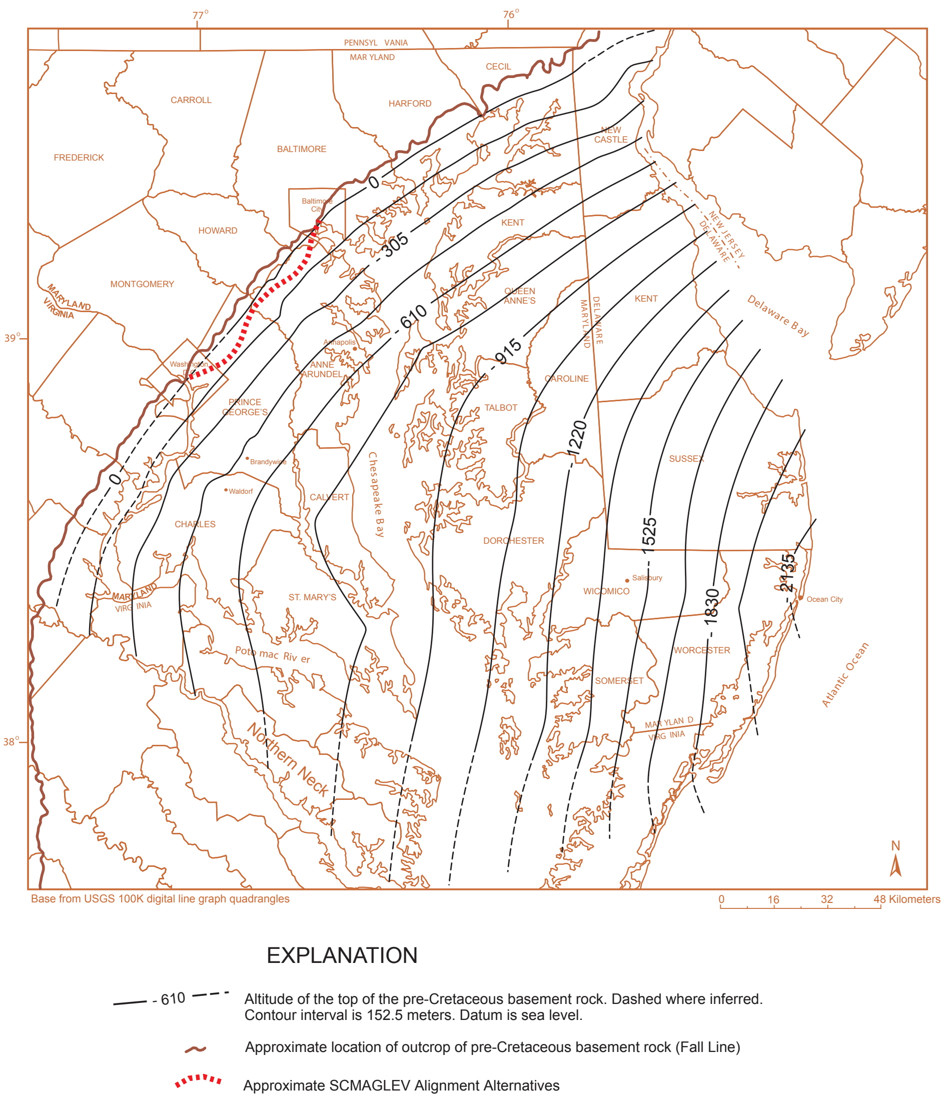


Figure 3. Altitude of the top of the pre-Cretaceous basement rock (after Hansen & Edwards Jr., 1986).

3.4 Groundwater

3.4.1 Groundwater Aquifer Systems

The Coastal Plain physiographic province of Maryland consists of unconsolidated sedimentary layers that serve as natural aquifers for eastern and southern areas of Maryland. As previously discussed, the sediments consist of sand, gravel, silt and clay that overly pre-cretaceous bedrock that ranges in age from Precambrian to Jurassic. The overlying sediments constitute a series of aquifers and confining units that serve as important freshwater sources for Maryland.

Tunnel sections for the proposed SCMAGLEV alignment alternatives will be through Cretaceous sediments of the Potomac Group (Figure 4). Three aquifer systems are present within the Potomac Group likely to be impacted by construction activities, including tunneling: 1) Upper Patapsco aquifer system, 2) Lower Patapsco aquifer system, and 3) Patuxent aquifer system. Each aquifer is separated by a confining unit, typically consisting of impermeable fine-grained sediment layering (Staley et al., 2009; Calis & Drummond, 2008).

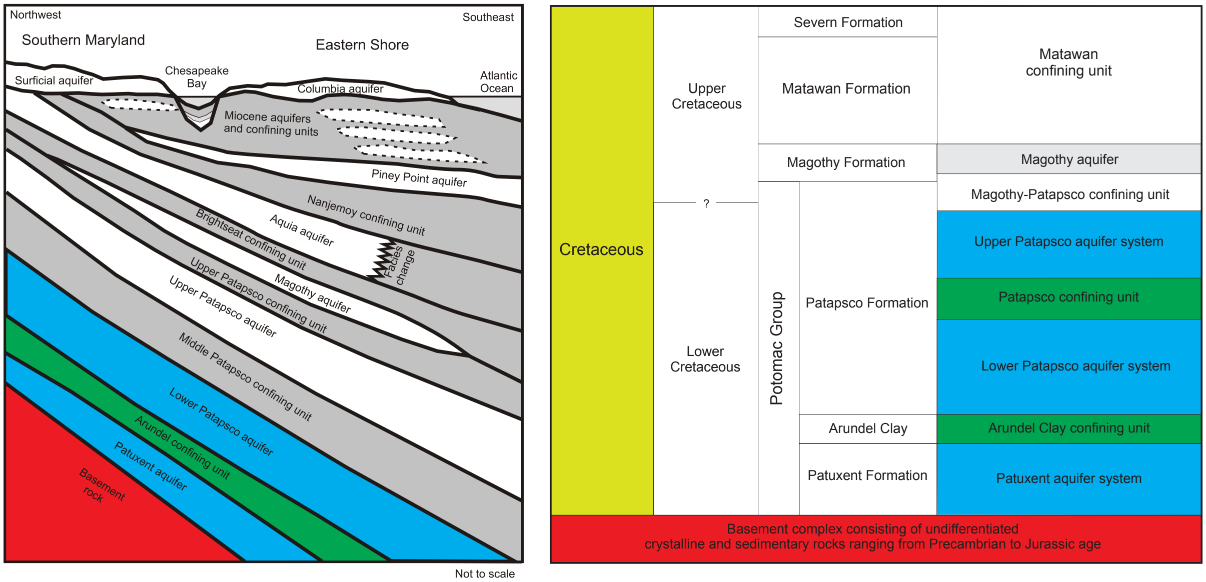


Figure 4. Schematic cross section of major hydrogeologic units in the Maryland Coastal Plain physiographic province with a reduced geologic time scale highlighting the age of the stratigraphic units to be encountered by the proposed SCMAGLEV alignment alternatives (after Drummond and Bolton, 2010).

3.4.2 Upper & Lower Patapsco Aquifer System

The Upper & Lower Patapsco aquifer system is of considerable importance as a water supply to Maryland's western shore, with a combined total use between the two permitted at approximately 70 Million gallons/day (Mgal/day) (Andreasen et al., 2013). The Upper and Lower aquifers are separated by the Patapsco confining unit, which consists of clays interbedded with fine quartz sand. The thickness of the confining unit varies with potential for gaps at thinner points of the bed through which hydraulic connectivity between the Upper and Lower Patapsco aquifer systems is possible. Confining unit thickness varies from approximately 5 m in Anne Arundel County to 88 m in Queen Anne's County. Hydraulic properties for the Upper and Lower Patapsco Aquifers and the Patapsco Confining Unit are summarized in Table 1.

Table 1. Hydraulic Properties for the Patapsco Aquifer System (Andreasen et al., 2013).

Unit	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storage Coefficient
Upper Patapsco Aquifer	0.6 – 282.9	12.2 – 45.7 (Vertical)	$8.4x10^{-5}$ – 0.0096
Patapsco Confining Unit	-	$1.8x10^{-7}$ – $4.5x10^{-7}$ (Vertical)	-
Lower Patapsco Aquifer	1.1 – 337.0	1.2 – 38.1 (Horizontal) 2.5 – 64 (Vertical)	$8.6x10^{-5}$ – 0.025

3.4.3 Patuxent Aquifer System

The Patuxent Aquifer system is a critical source of water on Maryland's western shore for Anne Arundel, Charles, Prince George's, and Cecil Counties. As of 2011 approximately 33 Mgal/d were permitted for use form the Patuxent aquifer system with the highest quantities from Anne Arundel county (18.8 Mgal/d), Baltimore County (7.78 Mgal/d) and Prince George's County (4.45 Mgal/d) (Andreasen et al., 2013). Available aquifer hydraulic properties are summarized in Table 2.

Table 2. Hydraulic Properties for the Patuxent Aquifer System (Andreasen et al., 2013).

Unit	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)	Storage Coefficient
Arundel Confining Unit	-	1.8×10^{-7} (vertical)	-
Patuxent Aquifer System	.6 – 621.6	0.6 – 58.5 (horizontal)	3.4×10^{-5} – 0.0012

3.4.4 Subsurface Gases

Radon is a commonly encountered gas within sediments and groundwater of the Coastal Plain. Radon is a gas produced by the radioactive decay of radium, which is a daughter element of Uranium. Radon, with a half-life of 3.8 days, produces its own daughter elements, including polonium. It is the production of radon daughter elements within one's lungs, due to breathing in radon gas, that constitutes the primary health risk (Otton, 1992). Uranium is present within all rocks in varying concentrations, and hence is also present within the unconsolidated sediments sourced from the rocks, including the Potomac Group and coastal plain alluvial deposits.

The Environmental Protection Agency (EPA) recommended levels for radon are <4 picocuries per liter (pCi/L) (US Environmental Protection Agency, 2016). The Maryland Department of Health maintains a database of radon levels measured in homes in Maryland between 2005 and 2016. Radon is present within Coastal Plain sediments; however, the overall recorded values are just above or below the EPA recommendations. Furthermore, the TBM pressurized face, in combination with a water-tight segmental lining and constant ventilation ensure no accumulation of radon during construction and during the post-construction lifespan of the structures.

The next phases of ground investigation, in addition to evaluating the radon content of sediments and groundwater along the project alignment, will also test for the presence of other gases such as methane and hydrogen sulfide. Additionally, future ground investigation efforts will search for the presence of contaminants within the surface and sub-surface that would be encountered during construction and tunneling.

3.5 Seismic Activity

Based on a review of 2018 United States Geological Survey (USGS) National Seismic Hazard Maps (Peterson et al., 2018), and Earthquake Hazard Maps for Maryland (Reger, 1999) the study area is located in an area of the United States with a low probability of seismic activity. The USGS identifies the eastern United States as a "Stable Continental Region" (SCR) because of its location in the center of a tectonic plate. Based on this geologic setting, the potential for seismic hazards has been deemed as low.

3.5.1 Recent Earthquake Activity (1990 – Present)

Maryland has experienced a number of earthquakes since 1990, all with magnitudes <3.0 which classify as minor (Maryland Geological Survey, 2010). This does not include earthquake epicenters located in surrounding states, which achieve magnitudes up to 5.8 (2011 Mineral, VA earthquake). The latest recorded earthquake in Maryland was recorded on November 11, 2017 and was classified as magnitude 1.5 (Intensity I).

4.0 GROUND CHARACTERIZATION

This section provides background information, definitions and explanations for the characterizations of the soil, bedrock and groundwater. Soil profiles are provided in Appendix C and D and geotechnical data report in Appendix F.

4.1 Soils

The soil deposits encountered in the underground excavations are heterogeneous. Soil descriptions are based on visual logging of cores and samples, Standard Penetration Test (SPT) and laboratory testing. The soils consist of interlayered layers and lenses of fine- and coarse-grained materials as classified by the Unified Soil Classification System (USCS).

For the purposes of this report, layers of soil materials have been identified based on grain size distribution and standard penetration test data. Soil units identifying:

a. Fill/Unconsolidated sediments
b. Mostly very stiff/hard clay/silt with very dense sand layer
c. Mostly very dense sand with very stiff/hard clay/silt layer

Distribution of Materials along the tunnel horizon (7.6 m above tunnel crown to 7.6 m below tunnel invert) identifying:

a. Predominantly Coarse-Grained Soils defined as soils with less than 50 percent passing the No. 200 Sieve and including soils classified as SC, SM, SP, SP-SM, SM-SC and GP.
b. Predominantly Fine-Grained Soils – defined as soils with more than 50 percent passing the No. 200 Sieve and including soils classified as CH, CL, CL-ML and ML.

4.2 Bedrock

Underlying the soils, the SCMAGLEV Alignment is located along a bedrock profile of varying depth. Bedrock along the SCMAGLEV alignment consists of metamorphic rock, in the form of gray gneiss, slightly to highly weathered (Appendix C and D). Overall, the rock Total Core Recovery (TCR) and Rock Quality Designation (RQD) indicate expected improving quality with increasing depth into bedrock as related to the degree of weathering decreasing with increasing depth. Bedrock will be encountered along the tunnel in the Washington, D.C. Station area which is slightly to moderately weathered.

Based on the lab test results, compressive strength of bedrock is between 124 to 284 MPa (estimated using Point Load Strength Index). Also, splitting tensile strength of bedrock is between 3.8 to 17.5 MPa. Rock abrasivity was assessed by means of Cerchar Method. Results show the abrasivity of bedrock is between 0.73 to 4.56 CAI which put the rock in low abrasive to extreme abrasive classes (BOTA Consulting Engineers, 2018) Rock testing is summarized in Table 3 below.

Table 3. Summary of bedrock lab testing results

Borehole	Splitting Tensile Strength (MPa)	Est. Compressive Strength (MPa)
DC-01	3.8	-
BWP-01	5.3	-
BWP-17	17.5	284.0
BWP-19	11.2	165.5
BWP-20	6.9 – 11.9	145.5 – 165.5
HW-01	-	124.1
HW-02	-	16.7

4.3 Groundwater

Estimated groundwater levels have been estimated on the geological and geotechnical alignment profiles (Appendix C and D) using a combination of field observations and installed piezometers. However, given the large distances between the exploratory boreholes, local variations in the groundwater are expected and a thorough groundwater monitoring program will be an important component of the next phase of geotechnical investigation, particularly with respect to seasonal fluctuations of the groundwater table.

5.0 EXISTING STRUCTURES

The buildings along the alignment are primarily commercial and residential. The commercial buildings consist predominantly of one- and two-story masonry and concrete structures with a few light one-story steel frame structures that house office and retail space. The residential buildings include high rises and single-family homes.

1. *Carnegie Library, Washington, D.C.* – Listed on the National Register of Historic Places, Carnegie Library has a shallow foundation system with continuous wall type foundation and local ground improvement under heavy columns on spread footings with stepped widening. This makes the structure sensitive to settlement and dewatering.

2. *Baltimore-Washington International Airport (BWI)* – BWI Airport serves over 25 million passengers annually. Tunneling will occur beneath critical infrastructure including runways and terminal facilities. The terminals include shallow pile support (approximately 12 m long) foundation system.

3. Other Construction Activities – Construction activities by other will potentially be taking place along the alignment while tunneling is occurring. In addition to surface activities, this also includes construction of the:

    - *Northeast Boundary Tunnel Project (NEBT)* – The NEBT is a 7 m diameter, 8,230 m long Combined Sewer Overflow (CSO) tunnel that is part of DC Water's Clean Rivers Project. The tunnel crosses above the MAGLEV alignment and construction is anticipated through 2023.

    - *Maryland Purple Line* - The Maryland Purple Line Project is a 26 km light rail line that will extend from Bethesda in Montgomery County to New Carrollton in Prince George's

County. The alignment is typically at-grade with minor stretches of elevated structures and a short underground section. Construction is anticipated to be completed by 2021.

6.0 PRELIMINARY DESIGN CONSIDERATIONS

6.1 Stations (Alignment Alternative J Modified 1 and J1 Option 5)

6.1.1 Washington, D.C. Station Alternatives (Mt. Vernon East & Mt. Vernon West)

6.1.1.1 Subsurface Conditions

The Mt. Vernon West Washington, D.C. Station alternative box construction would proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group sediments, weathered bedrock, and pre-Cambrian gneissic bedrock. Bedrock would potentially be encountered between -24 m El. and -37 m El. The unconsolidated sediments consist of very dense silty sands and very stiff/hard lean clays. Weathered bedrock horizon may include boulders of partially weathered material.

The Mt. Vernon East Washington, D.C. Station alternative would proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group sediments, weathered bedrock, and potentially pre-Cambrian gneissic bedrock. The bedrock would be encountered at approximately -20 m El. primarily at the western end of the station construction. The unconsolidated sediments consist of medium to very dense silty sands (SM), clayey sands (SC), hard sandy silts (ML) and a thick bed of very stiff lean clay (CL). Sandy gravels (GPS) are also likely to be encountered atop bedrock.

Groundwater levels within Washington, D.C. are encountered at approximately 3 to 5 m below ground level.

6.1.2 Baltimore-Washington International Airport Station

6.1.2.1 *Subsurface Conditions*

Station box construction will likely proceed through sediments of the Patapsco Fm. consisting of medium dense to dense sands (SP) and stiff silts (ML) with bands of stiff to hard lean clay (CL). Groundwater level is anticipated to be about 10 m below the existing grade level corresponding to an approximate elevation of +37 m El.

6.1.3 Cherry Hill Station, Baltimore, MD

6.1.3.1 Subsurface Conditions

The Cherry Hill Station alternative for Baltimore will be constructed atop very loose silty sands (Fill), dense to very dense silty sands (SM), thickly layered hard lean and fat clays (CL, CH) and very hard sandy silts (ML) and silty sands (SM). The silty sands sit unconformably atop gneissic bedrock at approximately -26 m El. Groundwater table is encountered at approximately 3.5 m (11.5 ft) below ground level.

6.1.4 Camden Yards Station Alternative, Baltimore, MD

6.1.4.1 Subsurface Conditions

The proposed Camden Yards Station would be constructed within the sand facies of the Potomac group with dense silty/clayey sands and potentially lenses of stiff clays and gneissic bedrock. Groundwater level likely sits at 3 to 5 m below ground level.

6.2 Tunnels & Shafts

Tunnel construction will be in water-bearing soils both above and below the groundwater table. Because tunneling will take place through built-up areas, control of ground losses and surface settlement to minimize damage to structures, buried utilities and streets along the alignment is a primary consideration for the selection of the tunneling method. The following sections discuss the general anticipated geological and geotechnical conditions anticipated along TBM runs for both alignment alternatives.

6.3 Alignment Alternative J Modified 1

6.3.1 Sta. 100+400 (Washington, D.C. Station) to Sta. 104+250 (Ventilation Plant & Substation)

6.3.1.1 Subsurface Conditions

The geology consists of unconsolidated fill and middle-Pleistocene alluvium, Potomac Group sediments, weathered bedrock (saprolite) of varying thickness, and Pre-Cambrian gneissic bedrock. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm. The saprolite is likely a very dense medium to coarse-grained silty sand with bedrock fragments and potentially weathered boulders. Gneiss bedrock is moderately to slightly weathered with slight to moderate fracturing.

Tunneling will proceed through a mixed face of bedrock and saprolite moving north from the Washington, D.C. station into the very dense sands of the Patuxent Fm. within which it will remain. The sediments likely to be encountered are classified as ML, SW, SM, and SC and are primarily medium to fine grained sands and silts, with potential localized clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.3.2 Sta. 104+250 (Ventilation Plant & Substation) to Sta. 108+150 (Ventilation Plant)

6.3.2.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.3.3 Sta. 108+150 (Ventilation Plant) to Sta. 112+950 (Ventilation Plant)

6.3.3.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands, into a long stretch within the Patapsco Fm./Arundel Fm. where the soils will be primarily hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML). The northern portion of the run will encounter mixed face conditions again with Patapsco Fm. clays and Patuxent Fm. dense to very dense silty sands. Both alignment alternatives will excavate within the groundwater table.

6.3.4 Sta. 112+950 (Ventilation Plant) to Sta. 119+450 (Portal)

6.3.4.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. and Patuxent Fm. sands/silty sands and fully within the Patapsco Fm., with hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML), until reaching the portal. Both alignment alternatives will excavate within the groundwater table.

6.3.5 Sta. 135+000 (Portal) to Sta. 141+600 (Ventilation Plant)

6.3.5.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.3.6 Sta. 141+600 (Ventilation Plant) to Sta. 146+500 (Ventilation Plant & Substation)

6.3.6.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.3.7 Sta. 146+500 (Ventilation Plant & Substation) to Sta. 151+100 (Ventilation Plant)

6.3.7.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL) and fat clays (CH) of the Arundel Fm. Both alignment alternatives will excavate within the groundwater table.

6.3.8 Sta. 151+100 (Ventilation Plant) to Sta. 153+200 (Portal)

6.3.8.1 Subsurface Conditions

The geology consists of unconsolidated fill, Cretaceous Potomac Group sediments, and weathered bedrock (saprolite). Tunneling will likely proceed through very hard lean clays (CL) and fat clays (CH) of the Arundel Fm., with local lenses of very dense, fine to medium grained sands (SP-SM). Tunneling may encounter weathered bedrock consisting of very dense, fine to medium grained silty sands (SM) and hard to very hard silts with rock fragments. Both alignment alternatives will excavate within the groundwater table.

6.4 Alignment Alternative J1 Option 5

6.4.1 Washington, D.C. Station

6.4.1.1 Subsurface Conditions

The Washington, D.C. Station construction will proceed through Fill, middle-Pleistocene alluvium, potentially Cretaceous Potomac Group Sediments, weathered bedrock, and potentially pre-Cambrian gneissic bedrock (depending upon selected station alternative). The unconsolidated sediments consist of very dense silty sands and very stiff/hard lean clays. Weathered bedrock horizon may include boulders of partially weathered material.

6.4.2 Sta. 100+400 (Washington, D.C. Station) to Sta. 104+250 (Ventilation Plant & Substation)

6.4.2.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.4.3 Sta. 104+250 (Ventilation Plant) to Sta. 108+150 (Ventilation Plant)

6.4.3.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed primarily through dense sands and silty sands of the Patuxent Fm. The sediments likely to be encountered are classified as SM, CL, and ML and are primarily fine to coarse grained silty sands, with stiff to hard lean clay lenses. Both alignment alternatives will excavate within the groundwater table.

6.4.4 Sta. 108+150 (Ventilation Plant) to Sta. 112+900 (Ventilation Plant)

6.4.4.1 Subsurface Conditions

The geology consists of unconsolidated fill and Pleistocene terrace deposits, and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands, into a long stretch within the Patapsco Fm. where the soils will be primarily hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML). The northern portion of the run will encounter mixed face conditions again with Patapsco Fm. clays and Patuxent Fm. dense to very dense silty sands. Both alignment alternatives will excavate within the groundwater table.

6.4.5 Sta. 112+900 (Ventilation Plant) to Sta. 119+950 (Portal)

6.4.5.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. The Potomac group sediments are typically very stiff/hard clays/silts w/very stiff sands for the upper deposits (Patapsco Fm.) and very dense sands with very stiff/hard clay/silt layers of the Patuxent Fm.

Tunneling will proceed through dense sands and silty sands of the Patapsco Fm. and Patuxent Fm., with the majority of the run within a clay-rich zone of the Patapsco Fm. The southern end of the run will be through a mixed face of the Patapsco Fm. clays and Patuxent Fm. sands and fully within the Patapsco Fm., with hard to very hard lean clays (CL) and fat clays (CH) with lenses of sandy silts (ML), until reaching the portal. Both alignment alternatives will excavate within the groundwater table.

6.4.6 Sta. 128+500 (Portal) to Sta. 134+950 (Ventilation Plant) and to Sta. 141+600 (Ventilation Plant)

6.4.6.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table

6.4.7 Sta. 141+600 (Ventilation Plant) to Sta. 146+500 (Ventilation Plant & Substation)

6.4.7.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL), fine to coarse grained, very dense sands (SW, SP), and very hard silts (ML). The Patapsco Fm. silty sands (SM) are fine to medium grained, very dense. Both alignment alternatives will excavate within the groundwater table.

6.4.8 Sta. 146+500 (Ventilation Plant & Substation) to Sta. 151+100 (Ventilation Plant)

6.4.8.1 Subsurface Conditions

The geology consists of unconsolidated fill and Cretaceous Potomac Group sediments. Tunneling will primarily proceed through fine to medium grained, very dense silty sands and very hard silts of the Patuxent Fm. Medium to coarse grained Clayey sands (SC) and lenses of very hard lean clays (CL) are likely to be encountered as well. Towards the norther end of the run, it is anticipated tunneling will encounter thicker layers of very hard lean clays (CL) and fat clays (CH) of the Arundel Fm. Both alignment alternatives will excavate within the groundwater table.

6.4.9 Sta. 151+100 (Ventilation Plant) to Sta. 153+200 (Portal)

6.4.9.1 Subsurface Conditions

The geology consists of unconsolidated fill, Cretaceous Potomac Group sediments, and weathered bedrock (saprolite). Tunneling will likely proceed through very hard lean clays (CL) and fat clays (CH) of the Arundel Fm., with local lenses of very dense, fine to medium grained sands (SP-SM). Tunneling may encounter weathered bedrock consisting of very dense, fine to medium grained silty sands (SM) and hard to very hard silts with rock fragments. Both alignment alternatives will excavate within the groundwater table.

6.5 Soil Stickiness

The cohesive nature of the excavated fine-grained materials is expected to impact excavation and spoils handling. Where significant quantities of fine-grained materials are present, handling difficulties such as clay lumping, balling and sticking must be expected. The excavated clay will be sticky, tend to clog the cutting wheel and air lock doors, and will be difficult to remove from the face and clog the spoils handling system. Preliminary ground investigation results along the alignment suggest large spans of tunneling within the Patapsco/Arundel Fm. that are rich in lean and fat clays and pose a great potential for stickiness.

Clay lumping, balling and sticking will require the use of conditioners and/or the use of water jets within the chamber to mitigate problems related to clay "stickiness." The excavated clay is likely to be slick and difficult to handle in the presence of water. The application of foam, bentonite, polymers or other conditioners can assist in reducing the "stickiness" and "slickness" of the clay. Efficient separation of the fines from the bentonite in the slurry separation plant must also be considered.

6.6 Soil Abrasion

Excavation and handling of the clays, sands, gravels, cobbles and boulders will abrade and wear the cutter head, the excavation chamber and the muck removal system. When tunneling tools are subject to excessive wear, penetration and thus the advance rate decreases. The tools have to be replaced during a maintenance interval, which leads to very high costs due to unplanned downtimes. With the help of wear prediction models, the wear of tools in dependency of the tunnel alignment geology could be investigated. Since at preliminary geotechnical boring program, no test has been done about soil abrasivity, it is recommended to do some tests like Soil Abrasion Testing (SAT) to help having more information regarding soil abrasivity along the tunnel alignment.

6.7 Ground Support in Tunnels

6.7.1 Tunnel Lining

A one-pass tunnel lining system, consisting of precast concrete segments, double gasketed for water control, bolted and dowelled together to form a continuous circular lining, will be the standard ground support. The double gasketed system provides redundancy and a means for effecting leak repair to prevent leakage of groundwater into the tunnel. The gasketed precast concrete tunnel lining installed by the TBM during excavation serves as the final lining. The permanent lining must be capable of resisting degradation when in contact with the anticipated natural soil and groundwater conditions. Short term (construction loading) and long-term conditions shall be considered in liner design. Also, anticipated soil behavior, like swell potential of fat clays/over consolidated clays and its impact on lining should be considered in segmental lining design.

6.7.2 Backfill Grouting

To minimize ground loss and reduce settlements, the void between the TBM excavation and the tunnel lining must be completely filled. The grout is installed through the tail of the shield as the tunnel is advanced. For adequate filling of the void, a grout pressure will be required in excess of the surrounding soil and water pressures, and grout volume must be placed behind the tail seals at a rate consistent with the excavation advance.

6.7.3 Break-outs and break-ins with TBM

Excavation out of the shaft into the ground (referred to as "break-out") required ground treatment to control groundwater flows, to stabilize soils, to minimize ground losses that would risk failure of the tunnel or excavation, and prevent unacceptable movement of existing structures and utilities.

7.0 CONSTRUCTION CONSIDERATIONS

7.1 TBM Excavation

Tunnel boring machine (TBM) selection will be important to addressing anticipated geologic conditions. Given groundwater and soil conditions an Earth-Pressure Balance Machine (EPBM) or Slurry Shield will likely be required for the majority of the tunnel alignment. Within the Washington, D.C. Station tunnel segments a mixed-face TBM (slurry-shield type) will likely be required to address the variable ground conditions consisting of gneissic (granitic) basement rock, dense/hard sediments, and high groundwater pressures.

7.1.1 Closed Face TBMs

The use of pressurized closed-face TBMs – either earth pressure balance (EPB) or slurry shield – with a one-pass gasketed segmental lining installed in the tail shield is required for tunneling. Without the application if a positive pressure to the face and around the shield, the soils will run, flow, and ravel. When operated effectively, closed face TBMs apply a positive pressure to the tunnel face and around the tunnel shield. This reduces the risk of soil inflows and groundwater flooding the tunnel, while minimizing ground losses that can result in surface settlements. This reduction in surface impacts is critical, as previously discussed, as tunnel construction proceeds beneath developed commercial and residential areas along the alignment. Generally, an EPB TBM operates more efficiently in finer grained soils whereas a slurry shield TBM is more efficient in coarser grained soils. The grain size distribution charts from the preliminary ground investigation are provided in Appendix B. A more detailed assessment will be needed with the next phase of ground investigation and selection of the type of TBM to be used will ultimately be the decision of the Design-Build Contractor.

For the pressure at the face and around the periphery of the shield to be effective in controlling ground loss, it must mobilize the internal friction within the soil mass. This supports the soils and prevents ground and groundwater movement towards the face and the shield. Fluctuations in the pressures applied will occur as the ground conditions and the compositions of the spoil or fluid within the working chamber of the TBM change.

For an EPB TBM, proper conditioning of the spoil within the excavation chamber is required so that it will act as a viscous fluid supporting the face. TBM operation that produces low support pressures can result in runs, caving and progressive instability of soils, particularly coarse-grained material in the face and should be avoided. High support pressures can result in excessive torque requirements for the cutting wheel. Arching of the spoil at the entrance to the screw conveyor inhibits discharge and should also be avoided. Fluctuations in the support pressure at the face as a result of changing ground conditions must be expected and planned for.

For a slurry shield TBM, the face pressure must be maintained by the use of bentonite slurry. It will be necessary to vary the density and constituents of the slurry and consider fluctuations in the types of soils being excavated and in groundwater conditions.

For the Washington, D.C. Station construction, a closed-face TBM with mixed face capabilities (e.g. slurry shield-type) will be required to account for tunneling through anticipated variable soil and rock-face conditions. The TBM would be designed to address ground conditions at the station including the presence of hard gneissic bedrock, very dense/hard sediments and high groundwater pressure.

7.2 Shaft Excavation & SOE

The methods of excavation are anticipated to use heavy excavation equipment such as backhoes or excavators, to excavate the very dense and stiff soils which may contain gravel, cobbles and boulders. The impact of dewatering must be considered with selection of shaft excavation method. For many, if not most locations along the alignment, any dewatering could result in settlement and adverse impacts to adjacent structures and should not be allowed. Additionally, the project construction will be within important aquifers of the Maryland western shore (see Section 3.4) and potential for adverse impacts needs to be carefully considered.

Sheeting by the use of sheet piles to reduce water infiltration into excavation and maintain excavation stability could be considered as well. Sheeting should be installed using high frequency oscillatory hammers to reduce/control vibrations. The D&B contractor should also consider the use of jet grouting to control water infiltration as well as silent pilers (for example GIKEN) to control vibrations in installing sheeting for deep excavations, shafts, etc.

7.2.1 Anticipated Ground Behavior for Support Installation and Shaft Excavation

Excavations for the shaft can be achieved using conventional excavation equipment such as track mounted hydraulically operated backhoes or excavators. Suitable drilling equipment can be used to drill holes for installation of the soldier piles for the initial support system. Heavy excavation equipment will be required to excavate the very dense soils containing gravel, cobbles and boulders, ground that has been grouted, and artificial fill. Abandoned and functioning utilities will also be found in the fill that the Design-Build Contractor will be required to relocate or remove, where necessary.

For general ground conditions at shaft locations, refer to geological/geotechnical discussion of alignment in Section 6.0 of this document, and the geological and geotechnical profiles for the alignment alternatives (Appendix C, D).

7.2.2 Pile Drilling

Drilling for piles must penetrate the dense to very dense soils. The holes will be subject to caving and deviation unless proper precautions are undertaken. Instability of drilled holes for piles will occur when holes encounter granular soils containing sand, gravel, cobbles and/or boulders both above and below

the water table. Where caving occurs, it will result in large backfill quantities. Casings, water and polymers, or slurry will be required to control the caving. The Design-Build Contractor must utilize appropriate drilling techniques, control the drilling rate and limit the number of passes down the hole to limit caving, and have casing and different types of drilling tools available at the job site for rapid use.
Deflection of the drilling tool when it encounters obstructions in fill (up to 1 meter in size), cobbles and boulders will cause deviations of holes. A coring bit should be available to drill through materials that will deflect the drill tool. Core drilling, backfilling of holes and re-drilling will be necessary to correct deviations and these activities will slow down the rate of advance of the holes.

Additives and slurries introduced into the borings to prevent caving must be effective over the full range of ground and groundwater chemistries anticipated in this project.

7.2.3 Slurry Wall Panel Installation

Reinforced concrete slurry wall (or diaphragm wall) panels forming straight walls along the sides of the excavations can provide an effective initial ground support system and groundwater cutoff for shaft excavation. To be effective, the slurry wall depth must be sufficient to provide a groundwater cutoff adequate to prevent inflow to the excavation and groundwater movements or the shaft bottom improved by grouting to be less permeable.

Hydromills, hydrofraises and clamshells with chisels are possible tools that can be used for slurry wall construction. By using bentonite slurry, the sidewall stability of the excavation can be maintained with control of slurry density used to avoid loss of slurry into the formation through the open zones. Because of the ground conditions, the excavation of panels will be subject to misalignment and remedial actions will be required when the panels are out of alignment. Over-excavation can occur where open zones, boulders or hard, dense, cemented zones are encountered that cause the mechanical excavator to drift out of alignment (and re-excavation is required to maintain panel verticality criteria). Over-excavation can also result if excessive slurry loss or insufficient slurry density causes sidewall instability and ground is lost into the excavation. These issues will lead to greater than anticipated excavation volumes.

7.2.4 Shaft Excavation

The methods of excavation are anticipated to use heavy excavation equipment such as backhoes and excavators, to excavate the very dense soils which may contain gravel, cobbles and boulders.
The excavated materials include both fine and coarse-grained deposits with particle sizes ranging from less than No. 200 sieve to granular material containing sands, gravels and cobbles and occasional boulders. Exposed soil conditions within the shaft excavation will vary. Changes will be gradational or abrupt, and will occur across the exposed surface as the excavation progresses. At D.C. station, shaft excavation will encounter the bedrock. For rock excavation, drill & blast (if allowed) or other appropriate methods would be considered.

For excavation carried out by a sequential excavation and support method, i.e., soldier pile and lagging and in the absence of groundwater, exposed wall heights should be limited such that they stand long enough to permit placement of lagging prior to sloughing of the soils. Lagging should be installed in a timely manner. Unsaturated sand, silt, silty sand, and clayey sand which are moist or have some apparent cohesion will ravel (within an hour) from unsupported sidewalls. Gravel, gravelly sand, poorly graded sand and silty sand above the groundwater table will ravel rapidly (within a few minutes) and running conditions should be anticipated. Flowing conditions must be anticipated in gravelly sand, poorly-graded sand, and well-graded sand below the water table or in the presence of semi-perched groundwater. Unsupported fine-grained soils will squeeze into the excavations, particularly where seepages from ground water occur.

When ground is exposed, raveling and ground loss will occur if lagging is not placed promptly. For an excavation supported by soldier piles and lagging, the migration of soils and the piping of fines from the soils through the lagging must be prevented by measures such as placement of filter materials behind the lagging in areas where raveling or water seepage (due to residual inflows, groundwater inflow or broken utilities) persists. Where relatively impermeable lagging (i.e. shotcrete) is used, effective drainage must be provided to reduce pressure on the support system.

7.3 Mined Cross Passages

7.3.1 Subsurface Conditions

One Washington, D.C. Station alternative would potentially require the construction of cross passages between twin tail tunnels with station platforms. Preliminary ground investigation boreholes suggest the cross passages would likely to be excavated through dense to very dense water saturated silty sands of medium to coarse grained size. The sediments are Holocene alluvium atop the pre-Cretaceous bedrock. However, the fully establish conditions, additional exploratory borings at the approximate location of each cross passage will be necessary to investigate site specific geotechnical conditions related to the soils, and groundwater present.

7.3.2 Groundwater

The range of groundwater levels is shown on the geologic and geotechnical profiles in Appendix C and D. The soils exposed in the cross passages will be below the groundwater table. For construction, the groundwater level at each cross-passage location will be established by the Design-Build Contractor.

7.3.3 Ground Improvement

Ground treatment is required to minimize groundwater inflows and prevent the ground from raveling, running and flowing in soils below the water table and in the presence of semi-perched groundwater. Ground treatment, e.g., jet grouting, permeations grouting (chemical or cement grout), must be performed prior to breakouts for the cross-passage excavations to improve the ground strength, to stabilize the ground around the existing tunnels; to increase stand up time for the excavation and allow installation of ground support; and, to control or limit groundwater inflows during excavation. An additional method that could be used is ground freezing, which will serve to stabilize soils and cut-off ground water inflow during excavation. Dewatering is not an option for soil stabilization, as it would likely induce settlement of adjacent surface structures. The Design-Build Contractor must consider groundwater conditions as well as surface access for ground treatment at each cross-passage site.

7.3.4 Method of Excavation

Methods of excavation and initial support for the cross passages must stabilize the mined excavations and limit surface settlement to avoid damage to existing surface structures, utilities and the main tunnels.

To achieve these goals, the methods must prevent soil losses and groundwater inflows. These will deprive the tunnel support system of the passive ground reaction necessary for stability and cause instability at the face of the cross-passage excavation. Use of the Sequential Excavation Method (SEM), utilizing pre-support and a heading and bench method of excavation is anticipated for the cross-passages. Where finer grained soils below groundwater are encountered at the bottom of the excavation the invert should be stabilized by means of crushed rock or a mud slab.

7.3.5 Break-outs and Break-Ins at Tunnel/Cross Passage Connections

As well as ground treatment to stabilize the ground at tunnel break-outs and break-ins, the tunnel lining must be given additional support over a length of tunnel sufficient to maintain the shape and stability of the lining. This support would likely be in the form of a steel breakthrough frame emplaced prior to initiation of break-through. This is critical to maintaining the segments in compression, which ensures stability of the lining and prevents groundwater inflow.

7.4 Soil Disposal and Handling

The large volumes of soils anticipated to be produced during excavation will require development of thorough plans for testing and disposal of the materials, which will be the responsibility of the Design-Build contractors. This includes considerations for treating the spoils if required (i.e. bentonite removal from slurry) as well as proper storage and disposal of any potentially contaminated ground. Preliminary disposal sites and disposal haul routes have been identified and are shown in Appendix E. The haul routes were selected to minimize impact of truck traffic to local communities while getting the trucks to main highways as efficiently as possible.

8.0 STRUCTURE PRELIMINARY FOUNDATION EVALUATIONS

Preliminary geotechnical data obtained from 23 boreholes show the subsurface has relatively uniform stratification and consists mostly of loose to medium (dense) sand to medium to stiff clay locally mixed with topsoil and fill in the upper 5-10 meters underlain by alternating/intercalated layers of very dense sand (SP/SW), silty sand (SM), Clayey Sand (SC), gravel (GP), locally with boulders, and very stiff-hard Silt and Clay, over bedrock gneiss which is typically hard and sound.

Depth to bedrock ranges from about 50 m. below the existing grade corresponding to approximate elevation of El.-30 m near Washington DC station; between the elevations El.-15 m. and El.-30 m in Greenbelt, MD area and about 30m. below the existing grade in Baltimore area with elevations in between El.-5 m and El.-8 m.

The boring logs and detailed description of each strata along with laboratory test results are presented in Geotechnical Data Report (BOTA Consulting Engineers, 2018).

8.1 Structure (Viaduct) Foundations

Preliminary engineering data suggested the elevated structures would be supported on 45m. (150 feet) span single pier reinforced concrete viaducts. Data obtained from the project's structural engineer show the following loads (Table 4) based on AREMA LFD (Load Factor Design) directives.

Table 4. Factored loads acting on 150-foot spaced viaduct pier

Load Combination Groups	Axial Load on Pier Base (P)	Axial Load on Pile Group (P)	Longitudinal Shear (Vx)	Transverse Shear (Vy)	Moment due to Transverse Force about Longitudinal Axis (Mx)	Moment due to Longitudinal Force about Transverse Axis (My)
I: 1.4 (DL + 5/3 LL + E)	9196 k	10893 k	0	0	0	0
IA: 1.8 (DL + LL + E)	11449 k	13630 k	0	0	0	0
II: 1.4 (DL + E + W)	8467 k	10164 k	91 k	140 k	7496 k.ft	4195 k.ft
III: 1.4 (DL + LL + E + 0.5W+WL+LF)	8904 k	10601 k	1051 k	112 k	8196 k.ft	85670 k.ft
VIII: 1.4 (DL + LL + E + Ice or Snow)	9067 k	10764 k	0	0	0	0

The soils in the upper 3 – 6 m (10-20 ft) generally do not carry the characteristics of a bearing strata to support the structure foundations. Also, the current and future urban development plans do not allow large foundation footprint areas. Considering the (large) magnitude of loads, stringent settlement/deflection criteria, unsuitable/low bearing soils, a deep foundation system was evaluated and selected. Of the deep foundation support because of large loads bearing ability, little or no vibrations during installations, drilled shafts were selected and recommended.

Different sizes of drilled shafts between 1.2 m (4 ft) and 3 m (10 ft) diameter were evaluated. The estimated drilled shaft capacity in compression, and the estimated settlements for each pile group is given in Table 5.

Table 5. Nominal Drilled Shaft Capacity and estimated settlements for different shaft sizes

Pile Diameter ft.(m)	Pile Length, ft. (m)	Axial Compression (tons)	Settlement in. (mm)	Settlement to failure in. (mm)	Comment
4 (1.2)	115 (35)	1,600	0.60 (15)	0.60 (15)	NG. Marginally safe
5 (1.5)	100 (31)	1,800	0.52 (13)	0.70 (18)	OK
6 (1.8)	120 (37)	2,800	0.65 (16)	0.80 (20)	OK
10 (3.0)	105 (32)	3,400	1.00 (25)	1.20 (31)	OK

It is likely that 1.5 m (5 ft) diameter, approximately 30.5 m (100 ft) long reinforced concrete drilled shafts, spaced minimum 4.6 m (15 ft) center-on-center, would adequately resist the viaduct structural loads.

8.2 Station Foundations

DC Station is to be located approximately 150 feet below the existing grade, the approximate bottom elevation of the station building is El.-100 feet (Apr. El.-31 feet). At this depth/elevation, the subgrade would consist of very dense silty sand/ hard clay over bedrock gneiss at shallow depths. A mat foundation is recommended to support the station structure. For conceptual/preliminary engineering the mat could be designed using an allowable bearing capacity of 10 tsf (tons square foot) and using a coefficient of subgrade reaction of 150 tons/ft^3.

The mat would need to be tied down to bedrock gneiss to resist hydrostatic forces.

8.3 Cut-and-Cover Tunnel and Portal Foundations

Both preferred alignments have two portals for the TBM (exit/entry) and transition cut-and-cover zones. Based on the review of the recent boreholes and the geological setting of the alignment (Appendix C, D and BOTA Consulting Engineers, 2018) a mat foundation is recommended for all portal structures. Generalized subsurface and geotechnical conditions are summarized below.

8.3.1 Alignment J modified 1

8.3.1.1 Sta. 118+810 to Sta. 119+441 (Cut-and-cover)

The subgrade would consist of alternating layer of dense, very dense sand and very stiff-hard clay. A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf (tons per square foot) and a coefficient of subgrade reaction of 130 pci (pounds cubic inch, using 12 in. by 12. plate) at or below El. +37 m (el. +120 ft). There would be a long-term settlement of less than 13 mm (0.5 in.). Groundwater would be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 9 m as the deadweight of the structure would resist uplift forces.

8.3.1.2 Sta. 119+441 to Sta. 119+950 (Tunnel Portal area)

Similar subgrade to section 8.3.1.1, but is less dense. The subgrade would need to be over-excavated 1.0m, and exposed surface as well as excavated soils would be re-placed in maximum 0.2 m lifts and each lift be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation can be designed using an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. plate) at or below El. +46 m (El. +150 ft).

8.3.1.3 Sta. 134+150 to Sta. 134+985 (Tunnel Portal Area)

The subgrade would consist of dense sand and stiff clay except the upper 1.5 m. Because of disturbance of the near-surface soils and surface disturbance, the foundation subgrade the upper 1.5 m of the exposed soils must be excavated and re-placed in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. Plate) at or below El. +71 m (el. +230 ft). There would be a long-term settlement of about 13 mm (0.5 in.).

Groundwater would likely be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be less than 3 m and the deadweight of the structure would resist uplift forces.

8.3.1.4 Sta. 134+985 to Sta. 135+234 (Tunnel Cut-and-cover)

The subgrade would consist of very dense Sand and hard Clay/Silt. A mat foundation would support the portal foundation. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.3m of the exposed soils must be excavated and re-placed in two lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat can be designed using an allowable bearing capacity of 3.0 tsf and a coefficient of subgrade reaction of 130 pci (using 12 in. by 12. Plate) at or below El. +53m (el. +170 ft). There would be a long-term settlement of about 13 mm (0.5 in.)

Groundwater would likely be encountered at the foundation bottom elevation within 10 feet. Temporary groundwater pumping would be required. Long term resistance to uplift forces is not likely required as the head would be less than 3 m. The deadweight of the structure would resist uplift forces.

8.3.2 Alignment J1 option 5

8.3.2.1 Sta. 119+520 to Sta. 119+941

The subgrade would consist of alternating layer of dense, very dense Sand and very stiff-hard Clay. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.5m of the exposed soils must be excavated and re-placed in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf and a coefficient of subgrade reaction of 120 pci (using 12 in. by 12. Plate) at or below El. +28 m (el. +92 ft). There would be a long-term settlement of about 13 mm (0.5 in.).

Groundwater is within 3 m of the foundation bottom. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 4.6 m. and deadweight of the structure would resist uplift forces.

8.3.2.2 Sta. 119+941 to Sta. 120+230 (Tunnel Portal area)

Similar subgrade to section 8.3.2.1, but is less dense. For uniform subgrade, an over-excavation of 1.0 m, and re-placing of excavated granular soils would be required. Backfill should be made in maximum 0.2 m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A foundation support can be used with an allowable bearing capacity of 1.5 tsf and a coefficient of subgrade reaction of 100 pci (using 12 in. by 12. plate) at or below El. +36 m (El. +118 ft).

8.3.2.3 Sta. 127+505 to Sta. 128+830

The subgrade would consist of very dense sand and very stiff/hard clay and silt. However, because of disturbance of the near-surface soils, the foundation subgrade the upper 0.5 m of the exposed soils must be excavated and re-placed in maximum 0.2m lifts and each lift must be compacted to 95 percent of the soils modified proctor density as observed in ASTM D 1557.

A mat foundation would support the portal foundation. A mat can be designed using an allowable bearing capacity of 2.5 tsf and a coefficient of subgrade reaction of 130 pc1 pci (using 12 in. by 12. plate) at or below El. +60 m (el. +196 ft). There would be a long-term settlement of less than 13 mm (0.5 in.).

Groundwater would likely be encountered at the foundation bottom elevation. Temporary groundwater pumping would be required. Long-term resistance to uplift forces is not likely required as the head would be about 3 m and the deadweight of the structure would resist uplift forces.

9.0 BUILDING AND UTILITY PROTECTION MEASURES

Disturbance of the ground as a result of tunneling can result in the settlement of existing structures (identified as buildings, utilities and other structures such as embankments and ramps) that are close to the construction activities. Settlement criteria that provide protection to the existing structures along the alignment will need to be developed in the project specifications. To meet these criteria and to demonstrate they are being met, the Contractor should:

- Evaluate ground movements caused by tunneling excavation
- Determine where structure protection is needed
- Design appropriate protection measures
- Monitor ground movements during construction to assure that the protection measures are sufficient to meet the criteria, and if necessary carry out remedial and/or additional protection measures. The monitoring program will monitor:
  - i. Ground movements and settlements caused by each tunnel as it approaches and passes beyond each monitoring station.
  - ii. Ground movements and settlements caused by cross passage excavations
  - iii. Confirmation that the settlement effects due to construction have ceased.
  - iv. Perform pre- and post-construction surveys to confirm the structures have not been damaged.

In addition to the grouting required for the protection of structures, ground treatment by means of permeation grouting with chemical or other suitable grout should be utilized by the contractor, particularly at sensitive locations such as beneath Carnegie Library, BWI Airport, etc.

9.1 Pre-Construction Surveys

Surveys of existing buildings and structures that may impacted by construction activities shall be conducted prior to the start of construction. The surveys will document the pre-construction conditions of the buildings and structures with high-definition photos and video that will allow a clear assessment post-construction if construction activities adversely impacted the structures. The pre-construction survey is typically complemented with the installation of optical crack gages on existing cracks and relevant instrumentation for monitoring settlement and vibrations during construction.

9.2 Construction Vibration

A Noise and Vibration Control Plan is prepared by each contractor for submission, which will include studies documenting baseline noise and vibration levels prior to the start of construction and tunneling. Remediation measures will be determined to address situations where noise and vibration levels have been exceeded. Noise and vibration monitoring points shall be established along the alignment during construction and tunneling operations with daily monitoring and additional monitoring if necessary in response to public complaints. Vibration limits are imposed to minimize the possibility of physical damage to buildings and to minimize annoyance to the public.

9.3 Instrumentation

An extensive program shall be emplaced during construction and tunneling operations to monitor for surface settlements. This includes an Alert Notification System that will generate messages to responsible personnel when data collected by an instrument is determined to be outside the established tolerances. Tolerance levels are established based on thresholds for buildings, roads and other sensitive structures to ensure remediation measures can be implemented immediately upon surpassing a tolerance level. Instrumentation would likely include Borehole Extensometers, Inclinometers, Tunneling Diameter Measure Device, Structure Monitoring Points, Ground Monitoring points, Utility Monitoring Points, Grid Crack Gauges, Tiltmeters, and Survey Instruments.

10.0 REFERENCES

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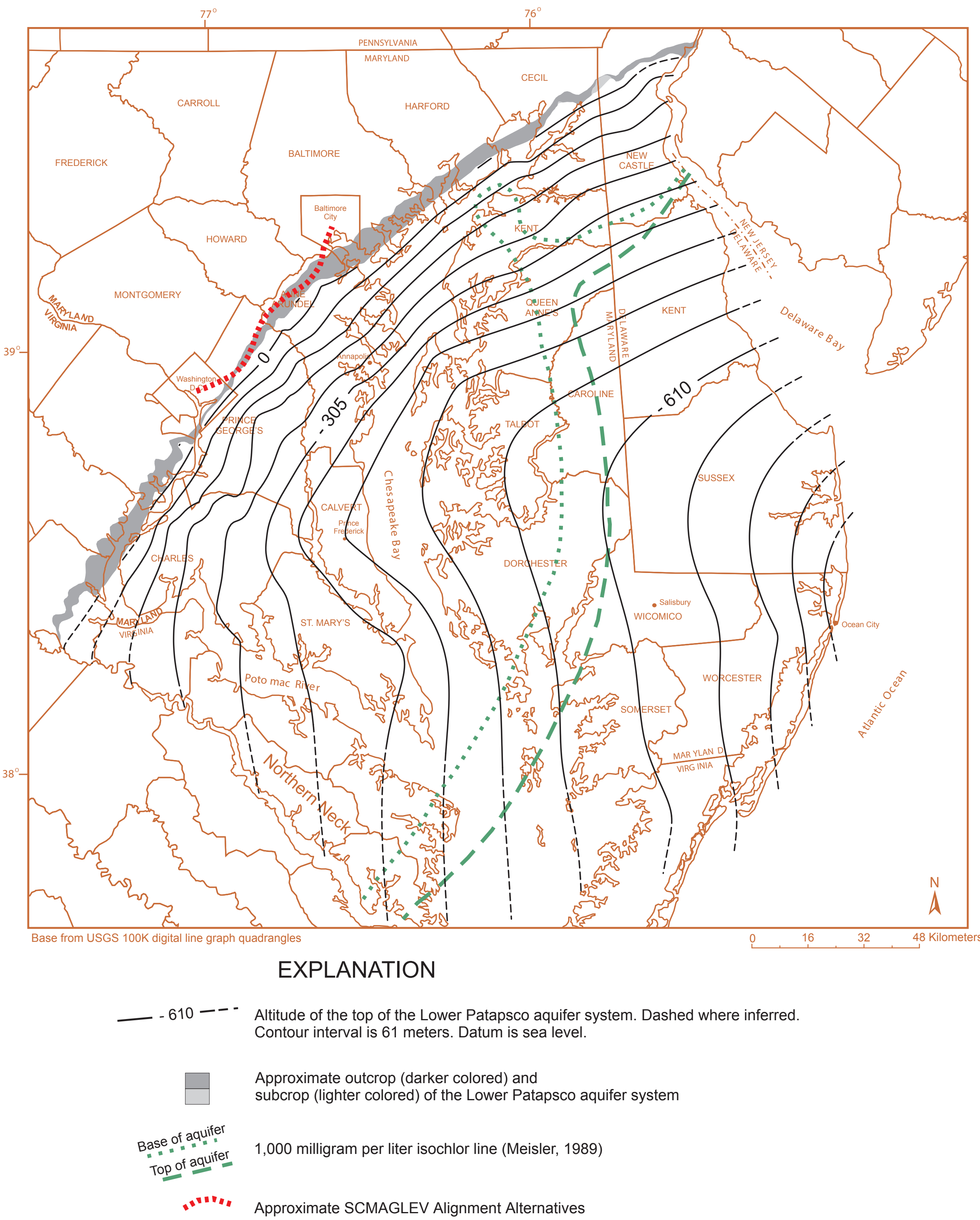
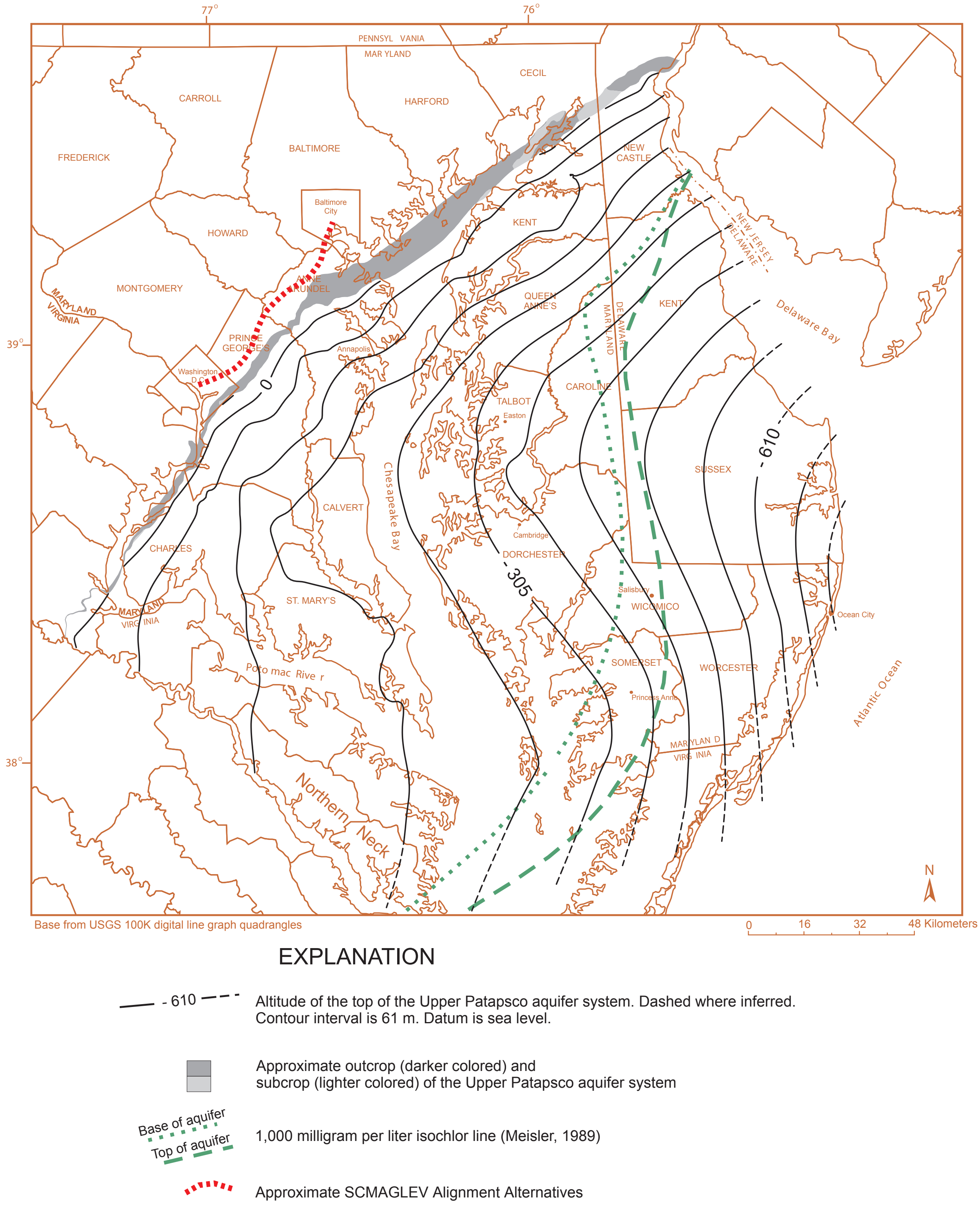
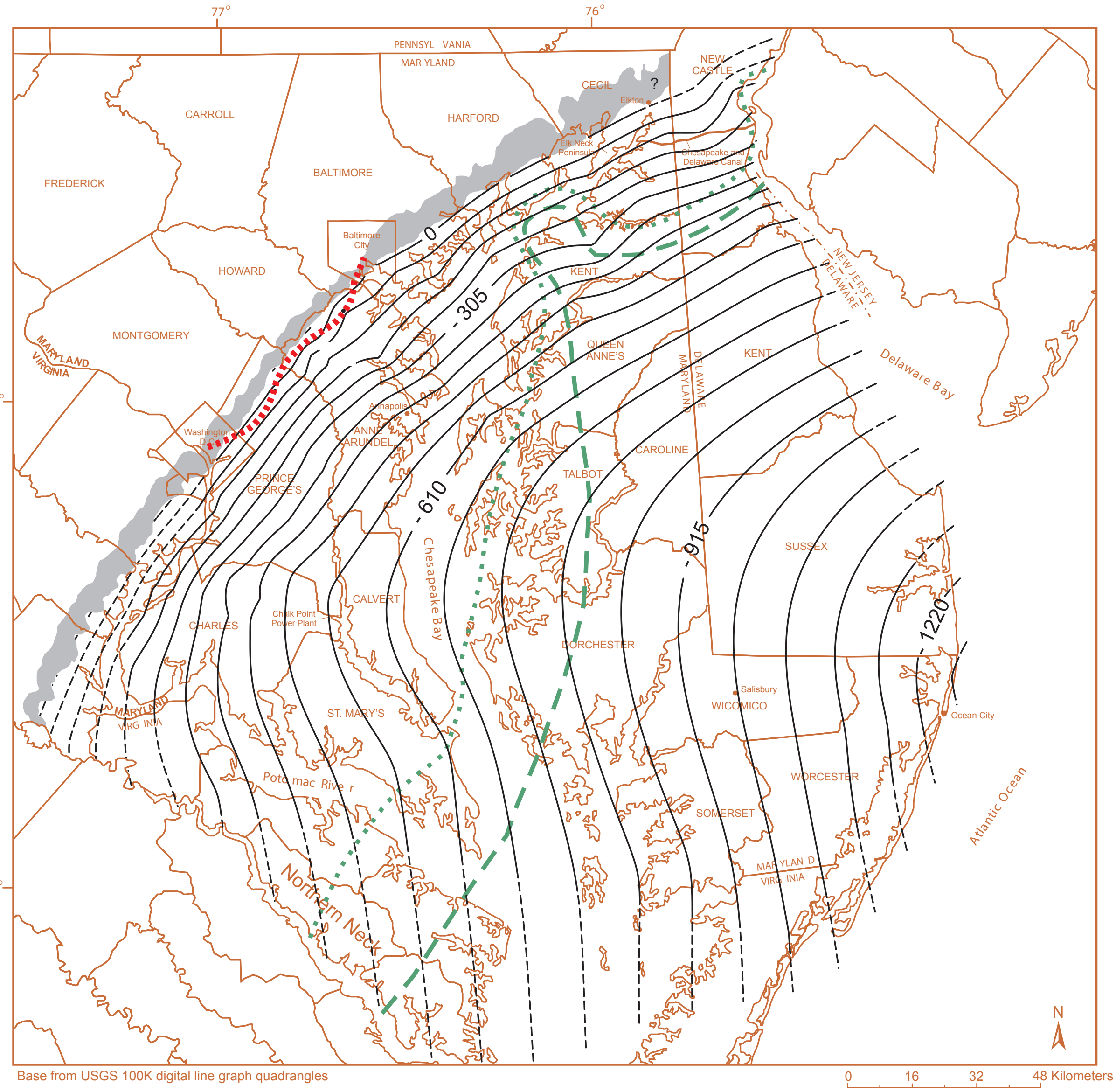
APPENDIX A: MAPS OF MARYLAND AQUIFERS



Altitude of the top of the Lower Patapsco aquifer system (after Andreasen et al., 2013)



Altitude of the top of the Upper Patapsco aquifer system (after Andreasen et al., 2013)



EXPLANATION

- 610 Altitude of the top of the Patuxent aquifer system. Dashed where inferred. Contour interval is 61 m. Datum is sea level.

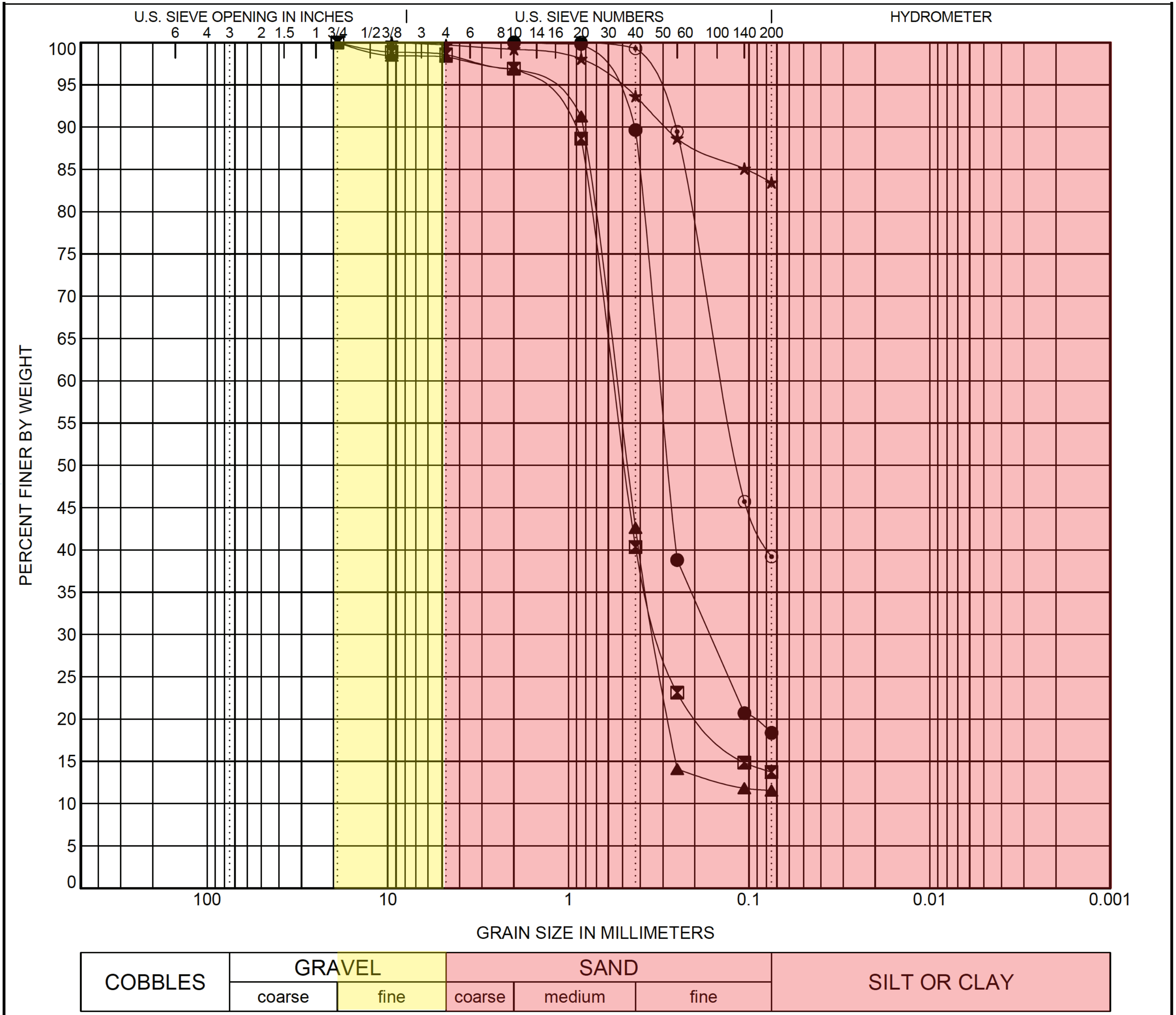
Approximate outcrop of the Patuxent aquifer system. Queried where uncertain.

Base of aquifer
Top of aquifer
1,000 milligram per liter isochlor line (Meisler, 1989)

Approximate SCMAGLEV Alignment Alternatives

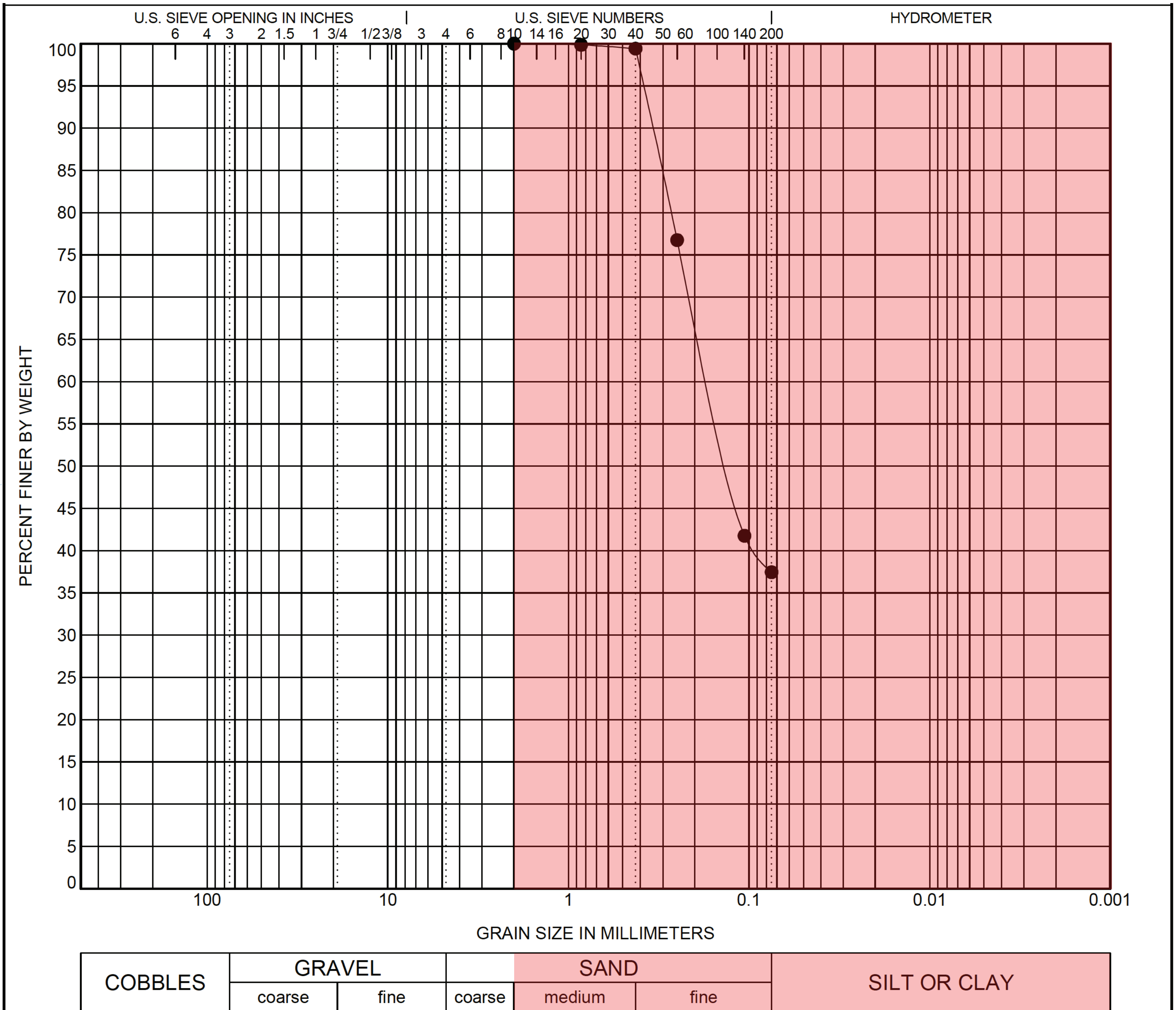
Altitude of the top of the Patuxent aquifer system (after Andreasen et al., 2013)

APPENDIX B: GRAIN SIZE DISTRIBUTION PLOTS



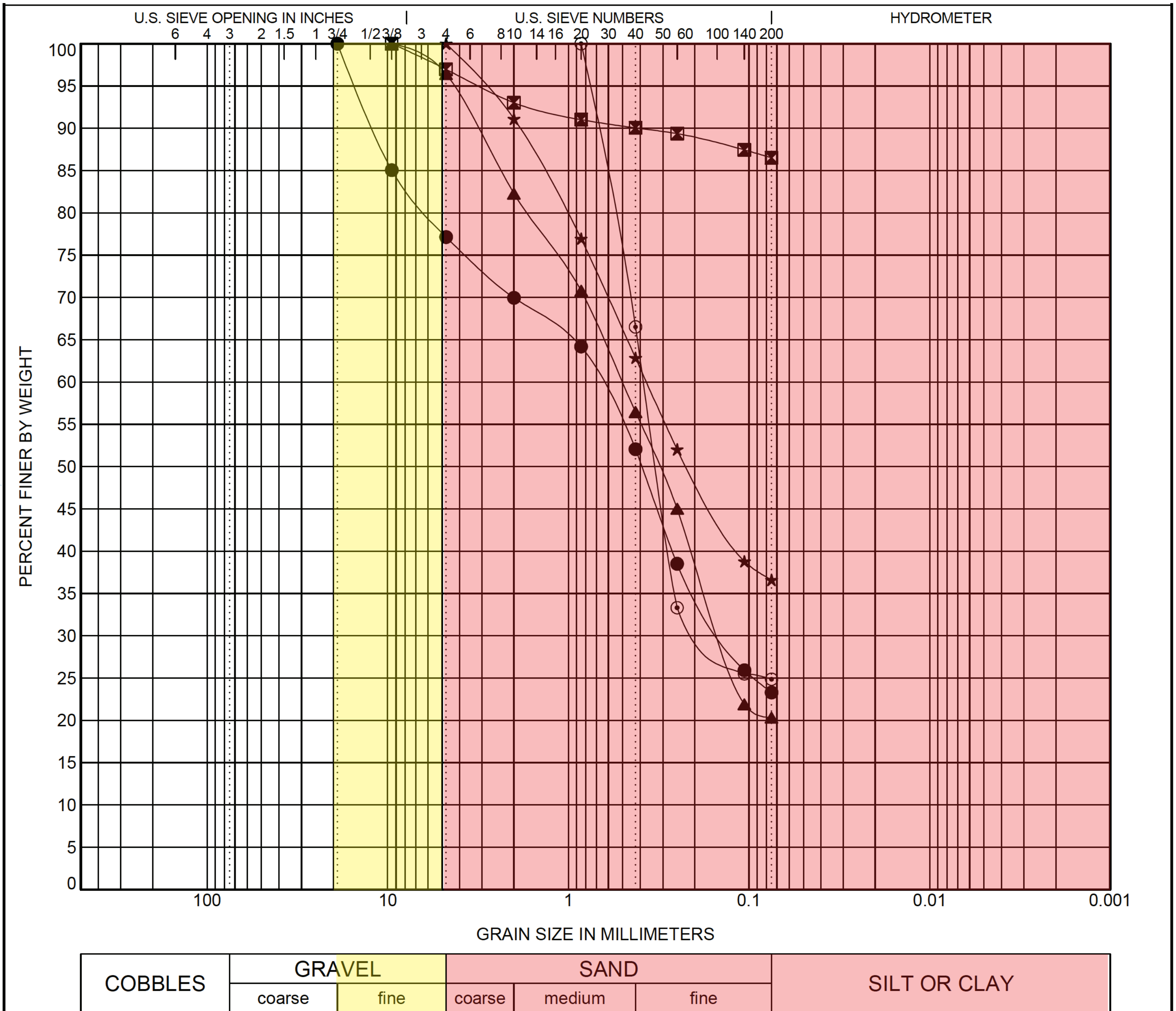
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	BWP-10	148.5-150	SILTY SAND(SM)	NP	NP	NP		
⌧	BWP-11	33.5-35	SILTY SAND(SM)	NP	NP	NP		
▲	BWP-15	30-31.5	POORLY GRADED SAND with SILT(SP-SM)	NP	NP	NP	20.44	53.64
★	BWP-15	80-81.5	SILT with SAND(ML)	NP	NP	NP		
⊙	BWP-15	135-136.5	SILTY SAND(SM)	NP	NP	NP		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BWP-10	148.5-150	2	0.312	0.165		0.0	81.6	18.4	
⌧	BWP-11	33.5-35	19	0.564	0.309		1.4	84.9	13.7	
▲	BWP-15	30-31.5	19	0.545	0.336		1.7	86.8	11.5	
★	BWP-15	80-81.5	9.5				0.3	16.2	83.5	
⊙	BWP-15	135-136.5	0.85	0.14			0.0	60.8	39.2	



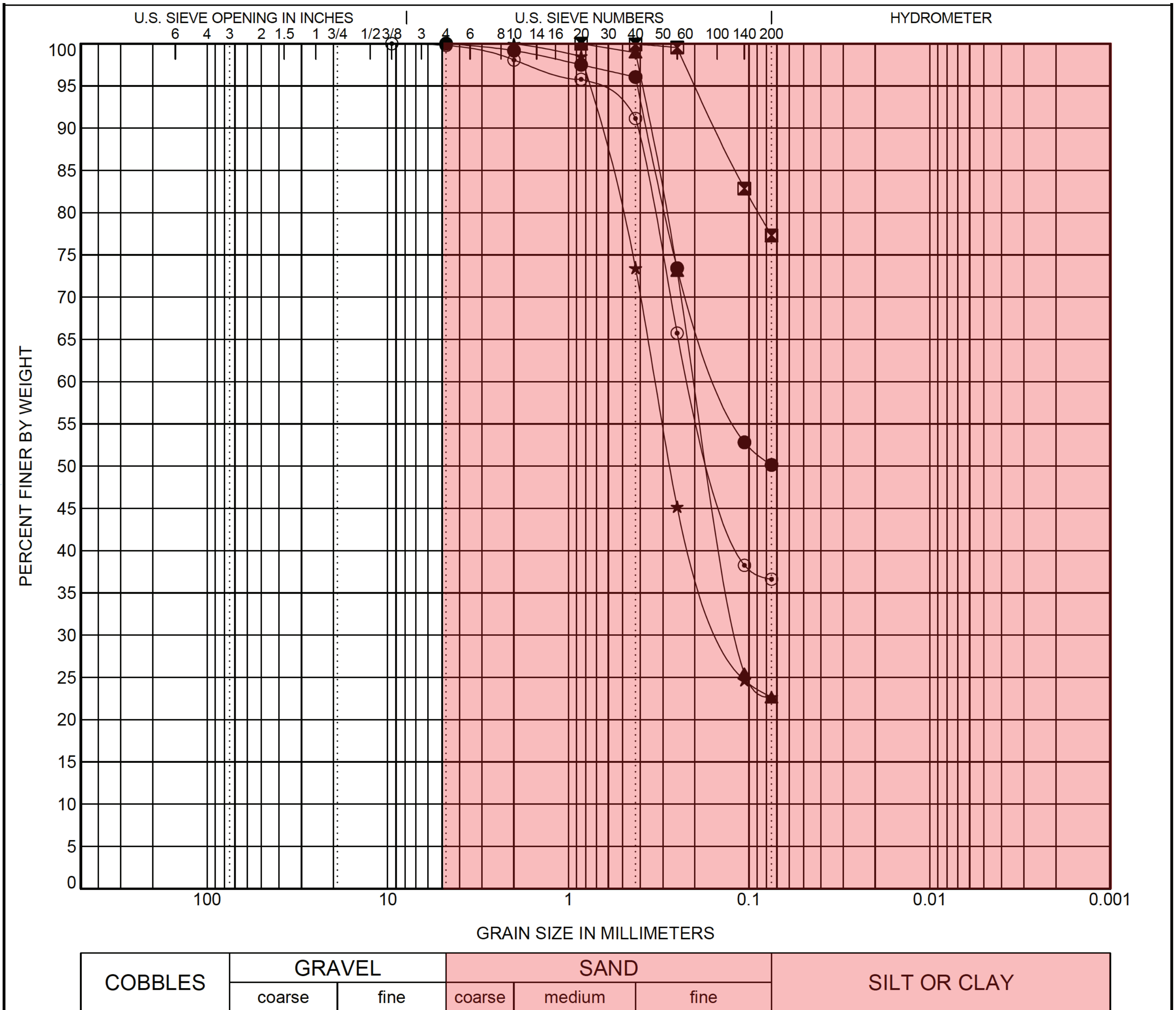
SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
● **BWP-15**	**200-200.5**	**CLAYEY SAND(SC)**	**37**	**23**	**14**		

SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● **BWP-15**	**200-200.5**	**2**	**0.166**			**0.0**	**62.6**	**37.4**	



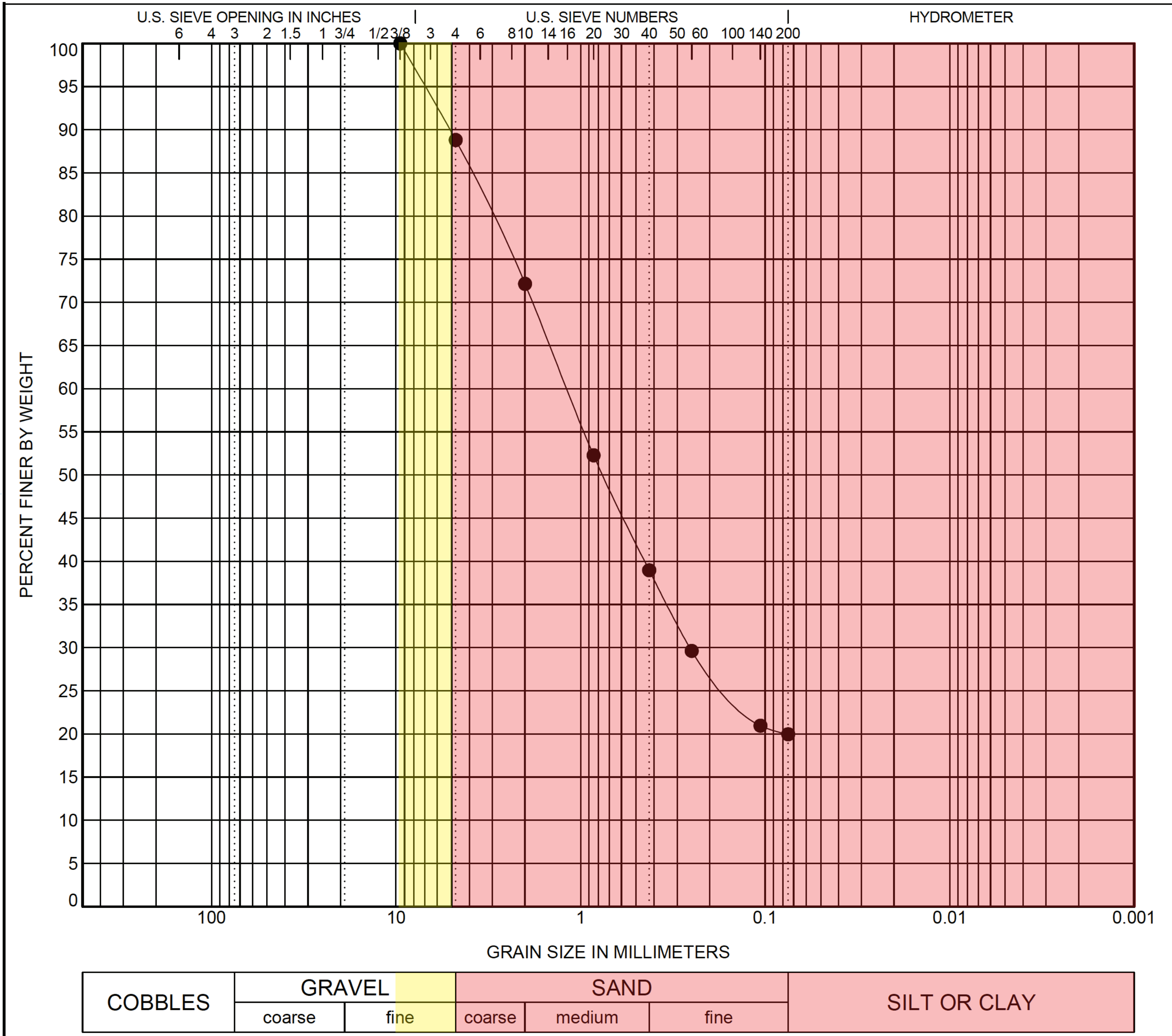
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-1**	**33.5-35**	**CLAYEY SAND with GRAVEL(SC)**	**37**	**21**	**16**		
⊠	**BWP-1**	**78.5-80**	**SILT(ML)**	**NP**	**NP**	**NP**		
▲	**BWP-1**	**111-112.5**	**CLAYEY SAND(SC)**	**39**	**22**	**17**		
★	**BWP-1**	**137-138.5**	**CLAYEY SAND(SC)**	**40**	**23**	**17**		
⊙	**BWP-3**	**83.5-85**	**CLAYEY SAND(SC)**	**39**	**23**	**16**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-1**	**33.5-35**	**19**	**0.669**	**0.14**		**22.9**	**53.9**	**23.3**	
⊠	**BWP-1**	**78.5-80**	**9.5**				**3.0**	**10.5**	**86.5**	
▲	**BWP-1**	**111-112.5**	**9.5**	**0.504**	**0.143**		**3.6**	**76.1**	**20.3**	
★	**BWP-1**	**137-138.5**	**4.75**	**0.369**			**0.0**	**63.4**	**36.6**	
⊙	**BWP-3**	**83.5-85**	**0.85**	**0.383**	**0.174**		**0.0**	**75.1**	**24.9**	



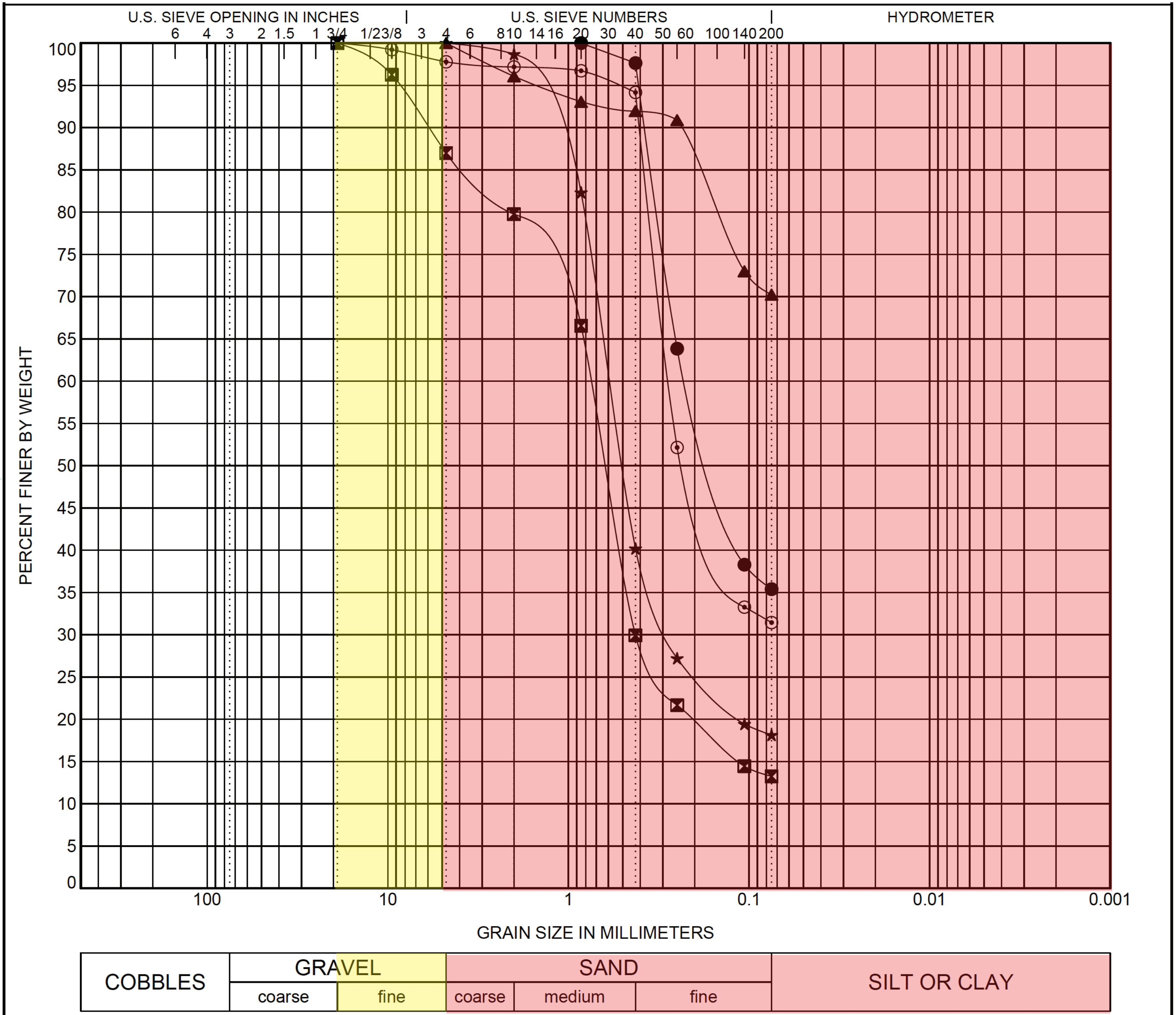
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-3**	**138.5-140**	**SANDY LEAN CLAY(CL)**	**38**	**21**	**17**		
⊠	**BWP-3**	**188.5-190**	**FAT CLAY with SAND(CH)**	**54**	**21**	**33**		
▲	**BWP-3**	**224.5-226**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
★	**DC-1**	**53.5-55**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**DC-1**	**78.5-80**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-3**	**138.5-140**	**4.75**	**0.143**			**0.0**	**49.9**	**50.1**	
⊠	**BWP-3**	**188.5-190**	**0.85**				**0.0**	**22.7**	**77.3**	
▲	**BWP-3**	**224.5-226**	**0.85**	**0.197**	**0.115**		**0.0**	**77.4**	**22.6**	
★	**DC-1**	**53.5-55**	**4.75**	**0.33**	**0.133**		**0.0**	**77.3**	**22.7**	
⊙	**DC-1**	**78.5-80**	**9.5**	**0.209**			**0.2**	**63.2**	**36.6**	



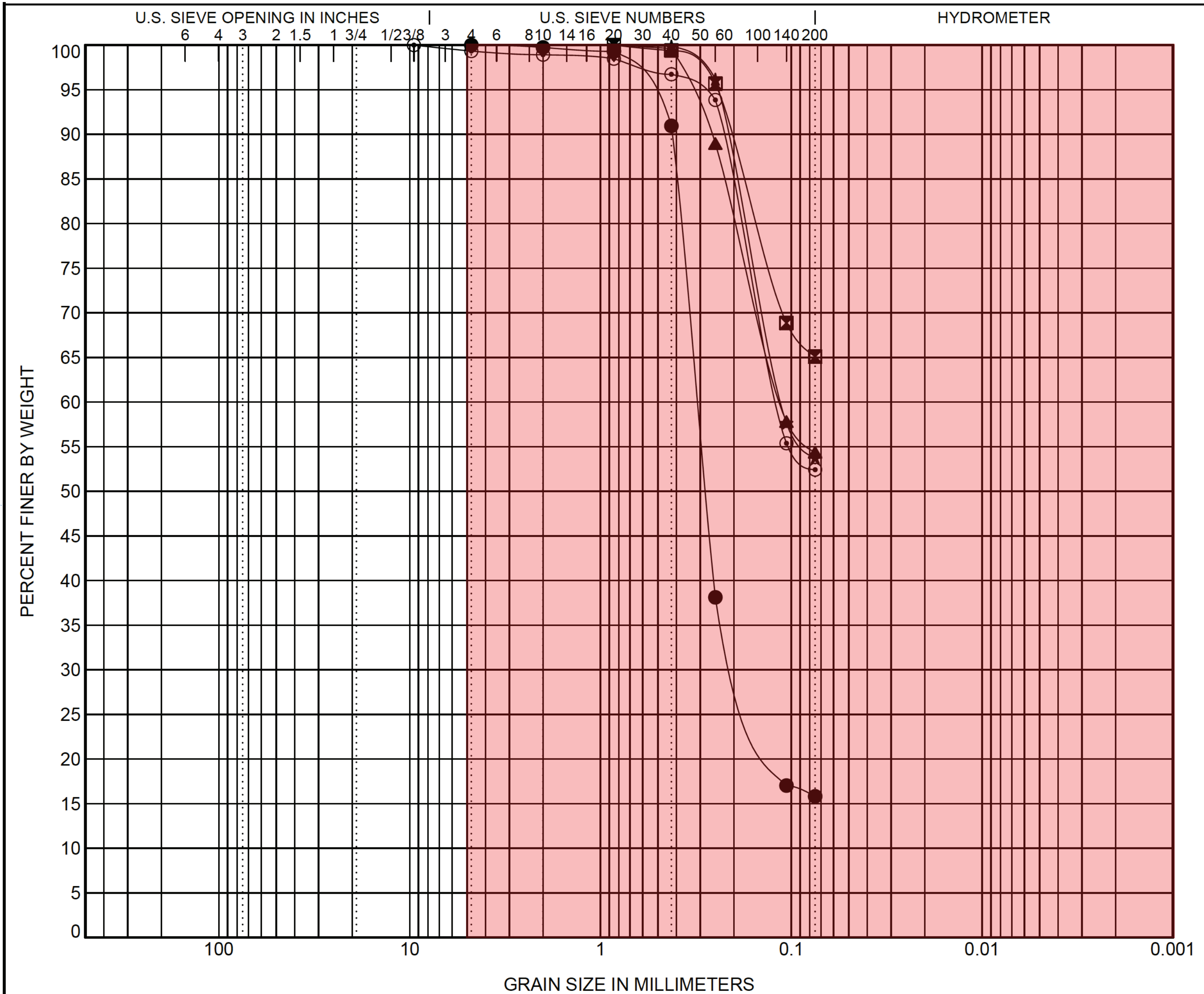
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**DC-1**	**118.5-120**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**DC-1**	**118.5-120**	**9.5**	**1.185**	**0.255**		**11.2**	**68.9**	**20.0**	



	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-2**	**68.5-70**	**SILTY SAND(SM)**	**40**	**27**	**13**		
⊠	**BWP-2**	**123.5-125**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-2**	**183.5-185**	**SILT with SAND(ML)**	**39**	**26**	**13**		
★	**BWP-3**	**248.5-250**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**BWP-3**	**303.5-305**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

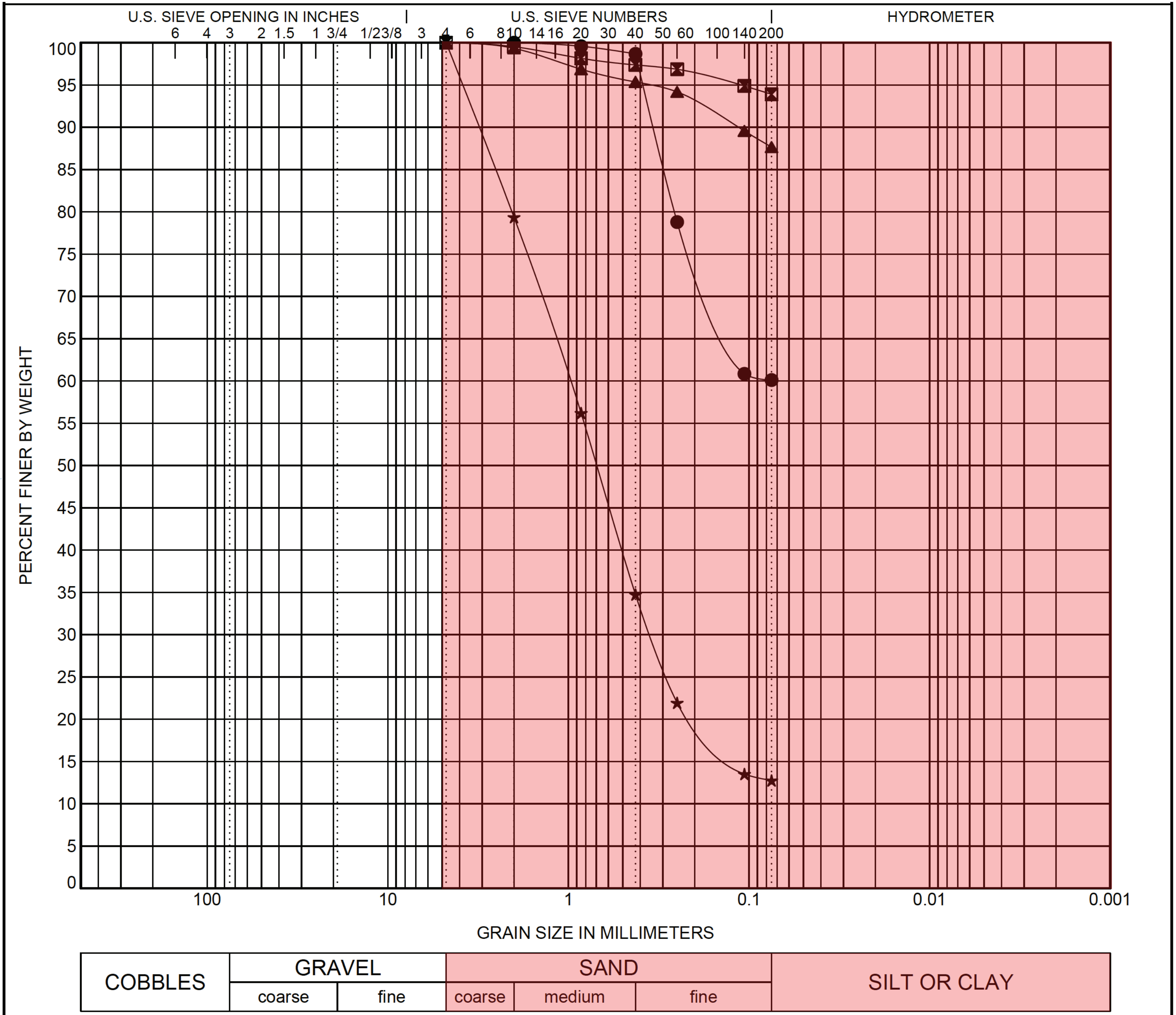
	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-2**	**68.5-70**	**0.85**	**0.22**			**0.0**	**64.6**	**35.4**	
⊠	**BWP-2**	**123.5-125**	**19**	**0.751**	**0.426**		**13.0**	**73.7**	**13.2**	
▲	**BWP-2**	**183.5-185**	**4.75**				**0.0**	**29.8**	**70.2**	
★	**BWP-3**	**248.5-250**	**4.75**	**0.589**	**0.28**		**0.0**	**81.9**	**18.1**	
⊙	**BWP-3**	**303.5-305**	**19**	**0.276**			**2.2**	**66.3**	**31.4**	



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

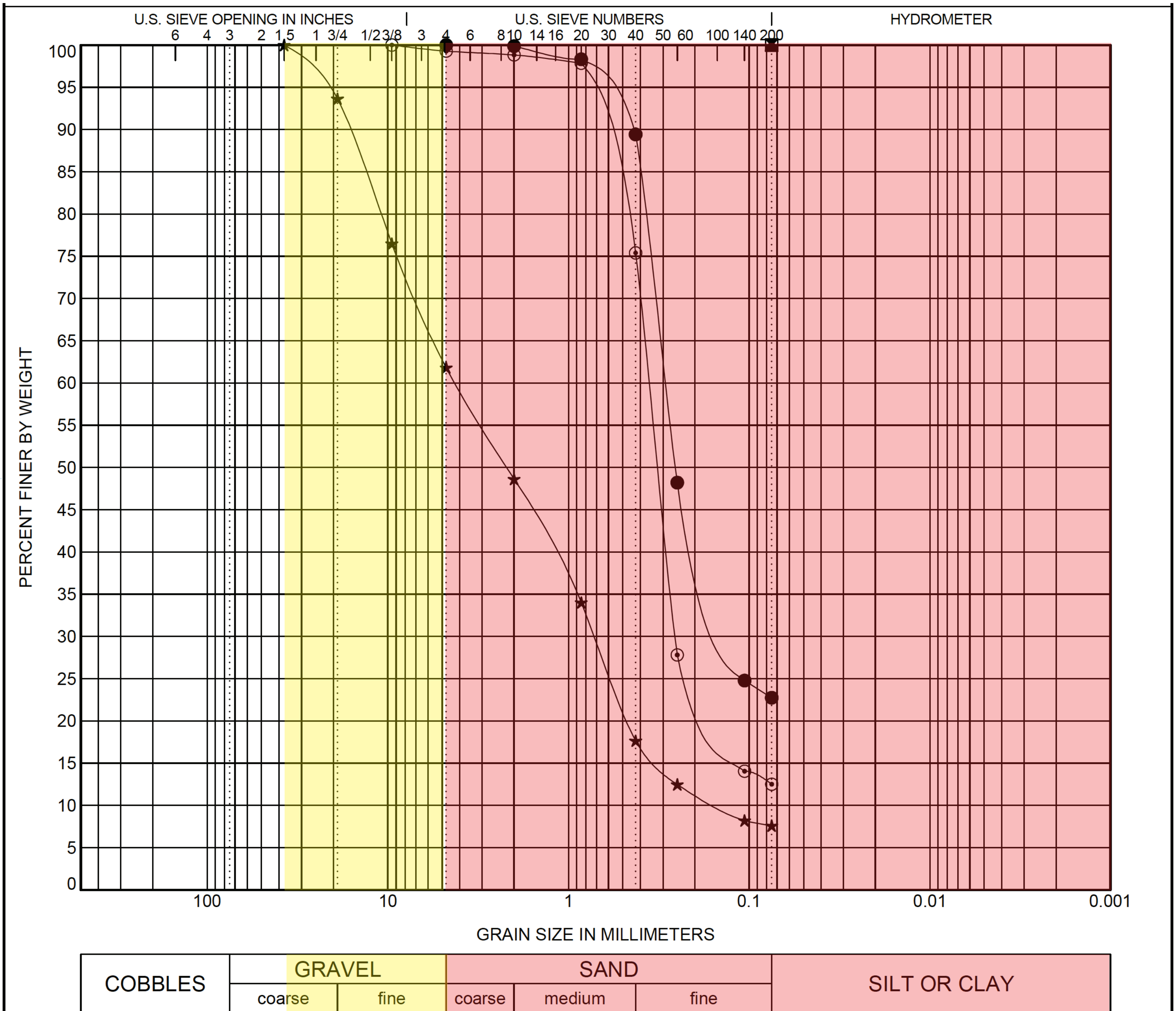
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	BWP-3	348.5-350	SILTY SAND(SM)	NP	NP	NP		
⊠	BWP-12	19-21	SANDY SILTY CLAY(CL-ML)	23	17	6		
▲	BWP-12	39-41	SANDY SILT(ML)	NP	NP	NP		
★	BWP-12	64-66	SANDY SILTY CLAY(CL-ML)	22	17	5		
⊙	BWP-12	184-186	SANDY SILT(ML)	NP	NP	NP		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BWP-3	348.5-350	4.75	0.311	0.18		0.0	84.2	15.8	
⊠	BWP-12	19-21	0.85				0.0	34.9	65.1	
▲	BWP-12	39-41	0.85	0.113			0.0	45.6	54.4	
★	BWP-12	64-66	0.85	0.112			0.0	46.2	53.8	
⊙	BWP-12	184-186	9.5	0.117			0.7	46.9	52.4	



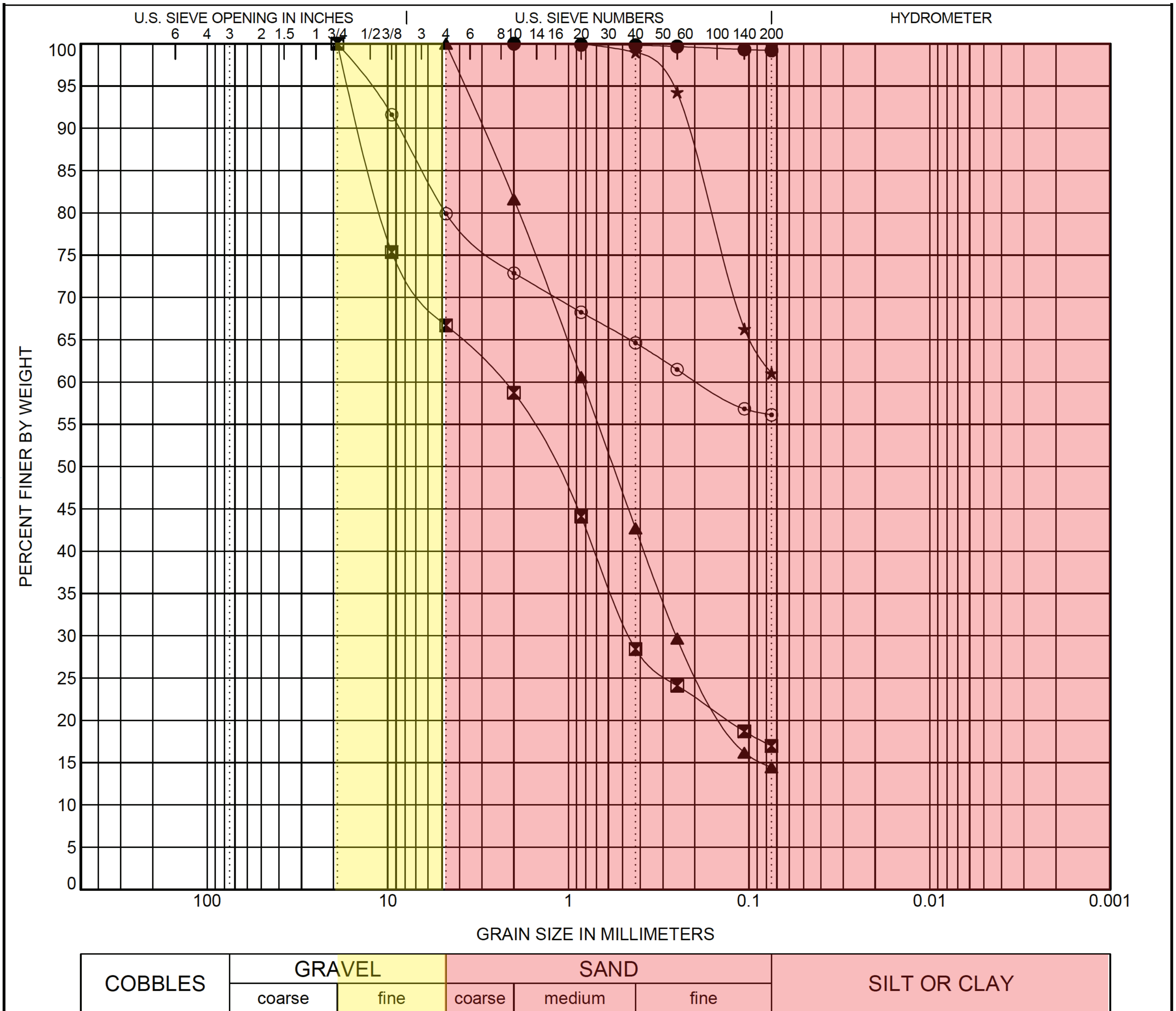
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-14**	**19-21**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
⊠	**BWP-14**	**84-86**	**SILT(ML)**	**NP**	**NP**	**NP**		
▲	**BWP-14**	**134-136**	**SILT(ML)**	**NP**	**NP**	**NP**		
★	**BWP-20**	**99-101**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-14**	**19-21**	**2**				**0.0**	**39.9**	**60.1**	
⊠	**BWP-14**	**84-86**	**4.75**				**0.0**	**6.1**	**93.9**	
▲	**BWP-14**	**134-136**	**4.75**				**0.0**	**12.3**	**87.7**	
★	**BWP-20**	**99-101**	**4.75**	**0.978**	**0.349**		**0.0**	**87.2**	**12.8**	



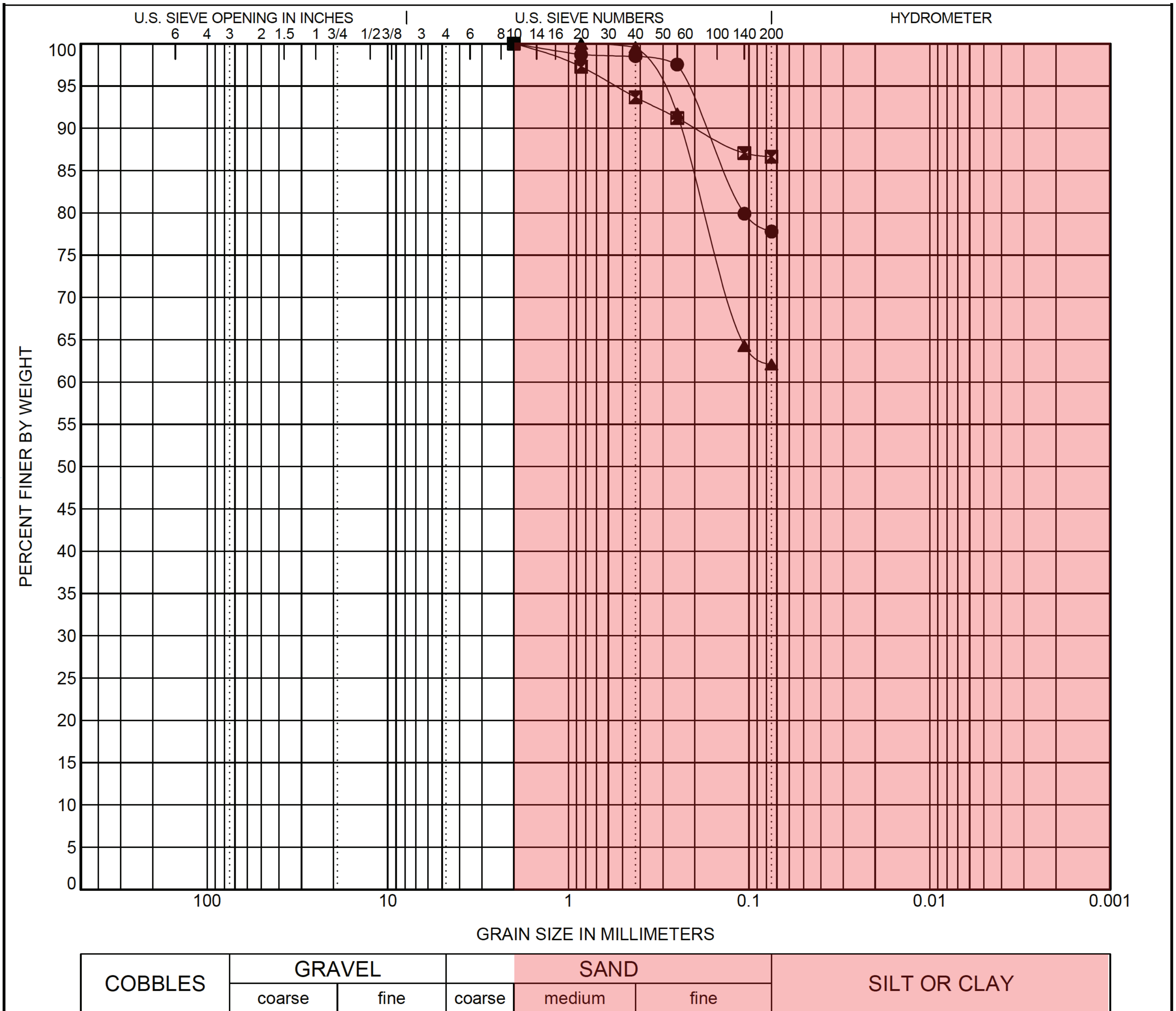
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-6A**	**33.5-35**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊠	**BWP-6A**	**53.5-55**	**LEAN CLAY(CL)**	**33**	**18**	**15**		
▲	**BWP-9**	**55-56.5**	**LEAN CLAY(CL)**	**34**	**18**	**16**		
★	**BWP-9**	**105-106.5**	**POORLY GRADED SAND with SILT and GRAVEL(SP-SM)**	**NP**	**NP**	**NP**	**0.80**	**27.76**
⊙	**BWP-9**	**165-166.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-6A**	**33.5-35**	**4.75**	**0.291**	**0.128**		**0.0**	**77.3**	**22.7**	
⊠	**BWP-6A**	**53.5-55**	**0.075**				**0.0**	**0.0**	**100.0**	
▲	**BWP-9**	**55-56.5**	**0.075**				**0.0**	**0.0**	**100.0**	
★	**BWP-9**	**105-106.5**	**37.5**	**4.215**	**0.717**	**0.152**	**38.2**	**54.2**	**7.6**	
⊙	**BWP-9**	**165-166.5**	**9.5**	**0.358**	**0.256**		**0.7**	**86.8**	**12.5**	



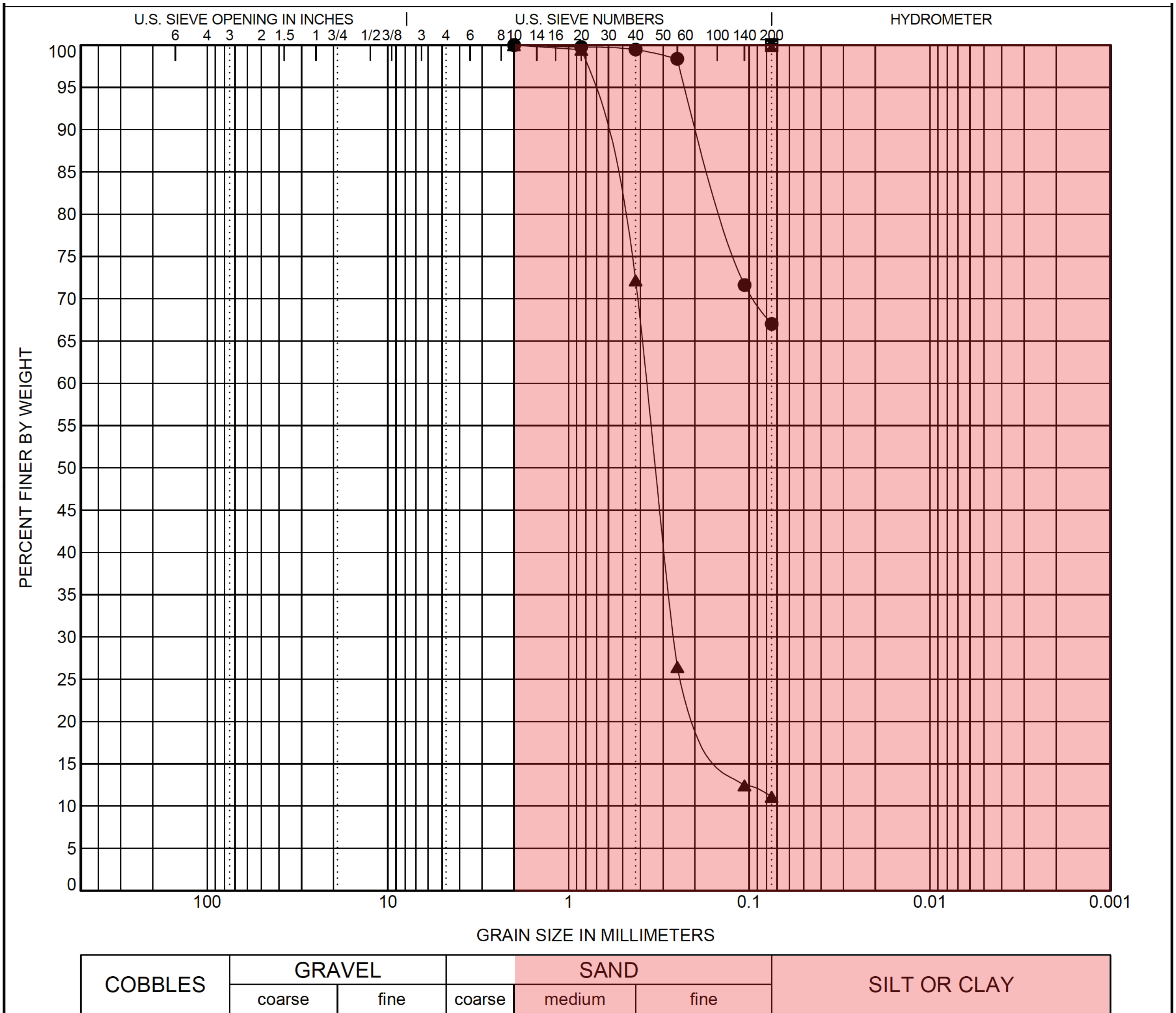
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	BWP-6A	83.5-85	SILT(ML)	NP	NP	NP		
⊠	BWP-17	130-131.5	CLAYEY SAND with GRAVEL(SC)	45	22	23		
▲	HW-1	74-76	SILTY SAND(SM)	NP	NP	NP		
★	HW-1	84-86	SANDY SILT(ML)	NP	NP	NP		
⊙	HW-1	24-26	SANDY SILT with GRAVEL(ML)	40	31	9		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BWP-6A	83.5-85	2				0.0	0.8	99.2	
⊠	BWP-17	130-131.5	19	2.299	0.456		33.3	49.7	17.0	
▲	HW-1	74-76	4.75	0.831	0.253		0.0	85.6	14.4	
★	HW-1	84-86	0.85				0.0	39.0	61.0	
⊙	HW-1	24-26	19	0.191			20.1	23.8	56.1	



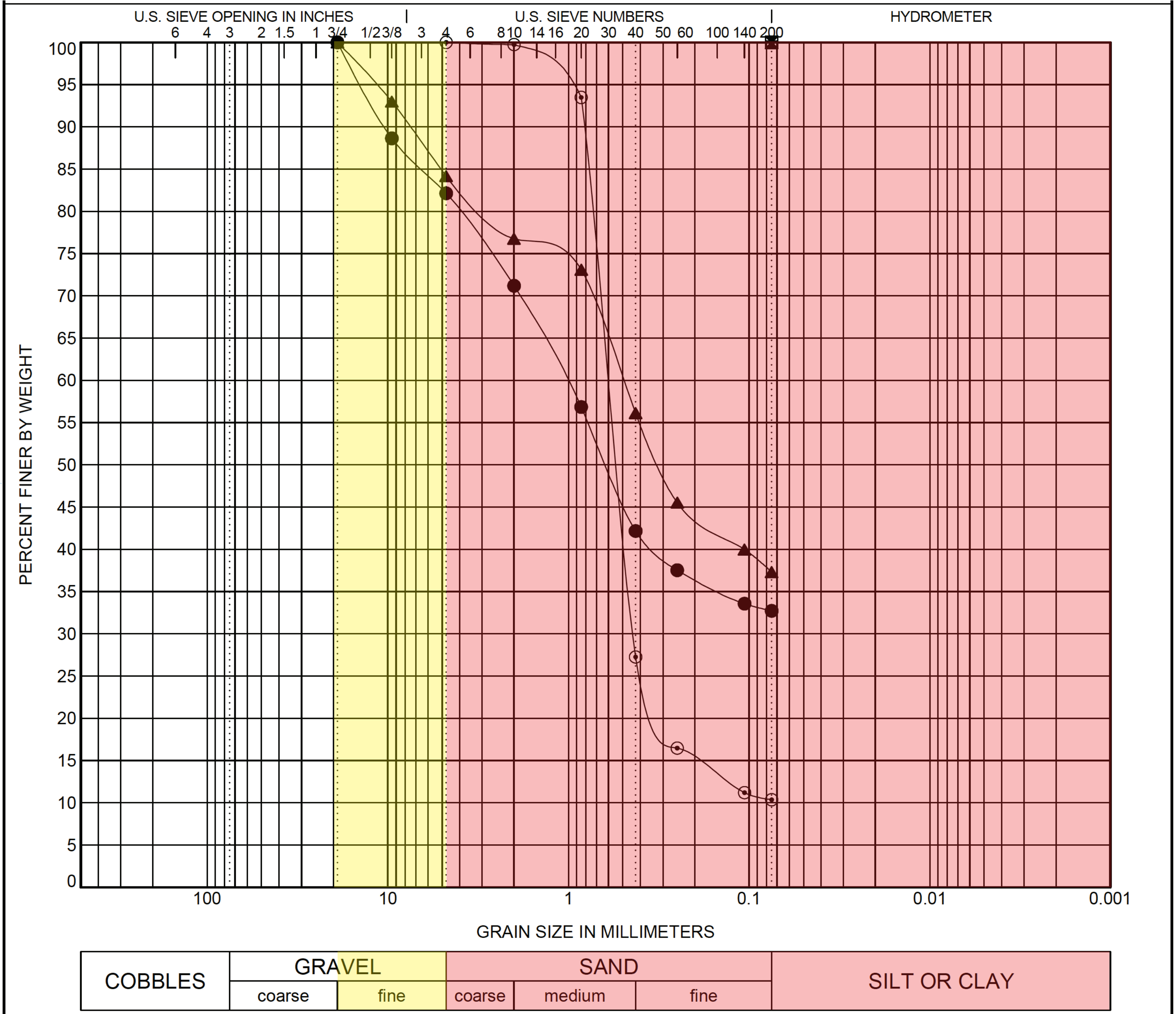
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**HW-1**	**54-56**	**LEAN CLAY with SAND(CL)**	**29**	**18**	**11**		
⊠	**HW-2**	**39-41**	**LEAN CLAY(CL)**	**37**	**21**	**16**		
▲	**HW-2**	**79-81**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**HW-1**	**54-56**	**2**				**0.0**	**22.2**	**77.8**	
⊠	**HW-2**	**39-41**	**2**				**0.0**	**13.4**	**86.6**	
▲	**HW-2**	**79-81**	**0.85**				**0.0**	**37.9**	**62.1**	



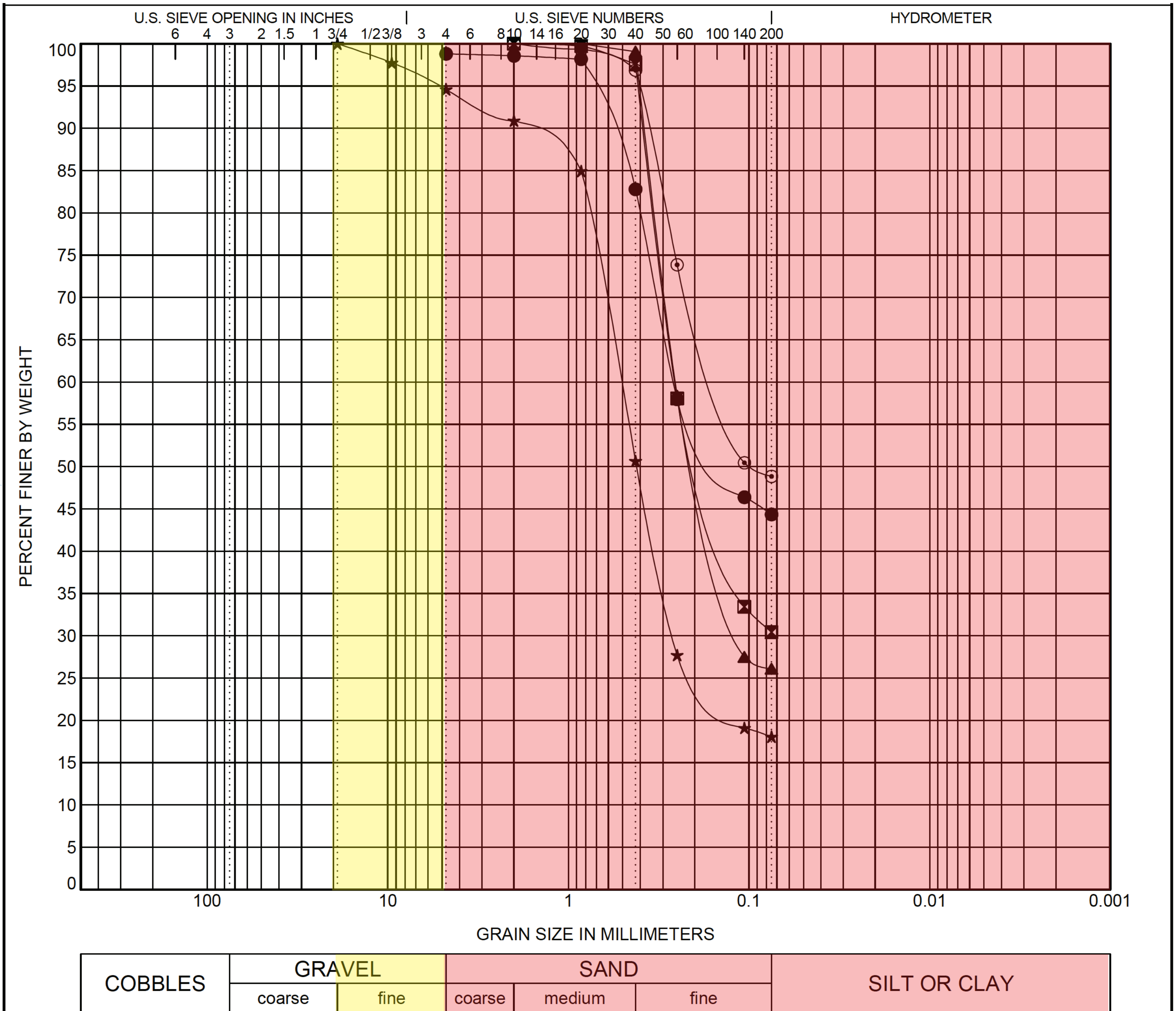
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-4**	**168.5-170**	**SANDY SILT(ML)**	**NP**	**NP**	**NP**		
⊠	**BWP-4**	**188.5-190**	**LEAN CLAY(CL)**	**39**	**20**	**19**		
▲	**BWP-6**	**23.5-25**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**3.24**	**6.51**
★	**BWP-6**	**68.5-70**	**LEAN CLAY(CL)**	**43**	**21**	**22**		
⊙	**BWP-10**	**203-205**	**SILT(ML)**	**35**	**27**	**8**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-4**	**168.5-170**	**2**				**0.0**	**33.0**	**67.0**	
⊠	**BWP-4**	**188.5-190**	**0.075**							
▲	**BWP-6**	**23.5-25**	**2**	**0.369**	**0.261**		**0.0**	**88.9**	**11.1**	
★	**BWP-6**	**68.5-70**								
⊙	**BWP-10**	**203-205**								



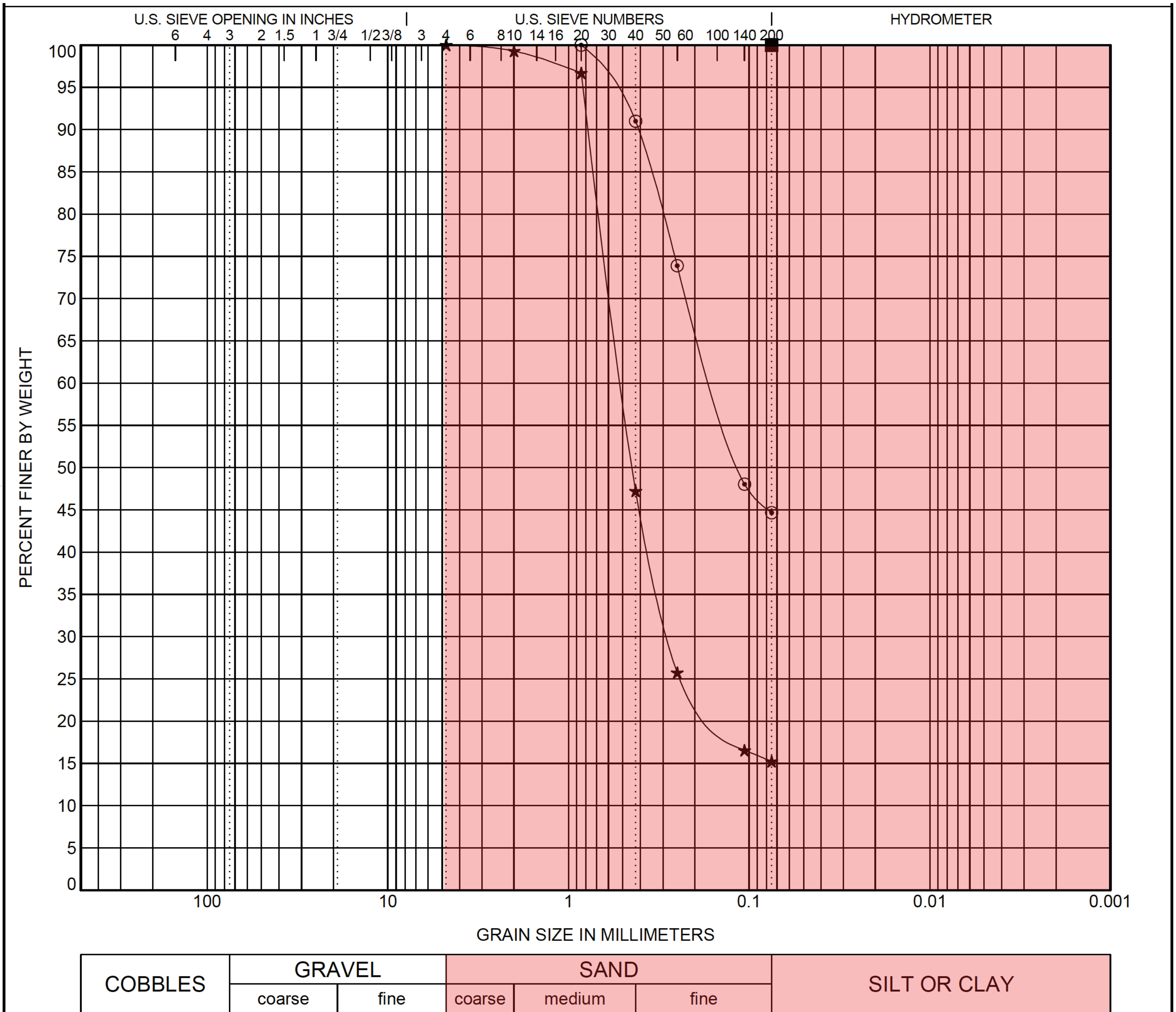
	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	BWP-11	73-75	**SILTY SAND with GRAVEL(SM)**	NP	NP	NP		
⊠	BWP-11	108-110	**SILT(ML)**	36	27	9		
▲	BWP-11	138-140	**SILTY SAND with GRAVEL(SM)**	NP	NP	NP		
★	BWP-11	173-175	**SILT(ML)**	35	27	8		
⊙	BWP-13	34-36	**POORLY GRADED SAND with SILT(SP-SM)**	NP	NP	NP	4.95	9.28

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BWP-11	73-75	19	1.026			17.9	49.4	32.7	
⊠	BWP-11	108-110								
▲	BWP-11	138-140	19	0.498			15.8	46.9	37.3	
★	BWP-11	173-175								
⊙	BWP-13	34-36	4.75	0.599	0.437		0.0	89.6	10.4	



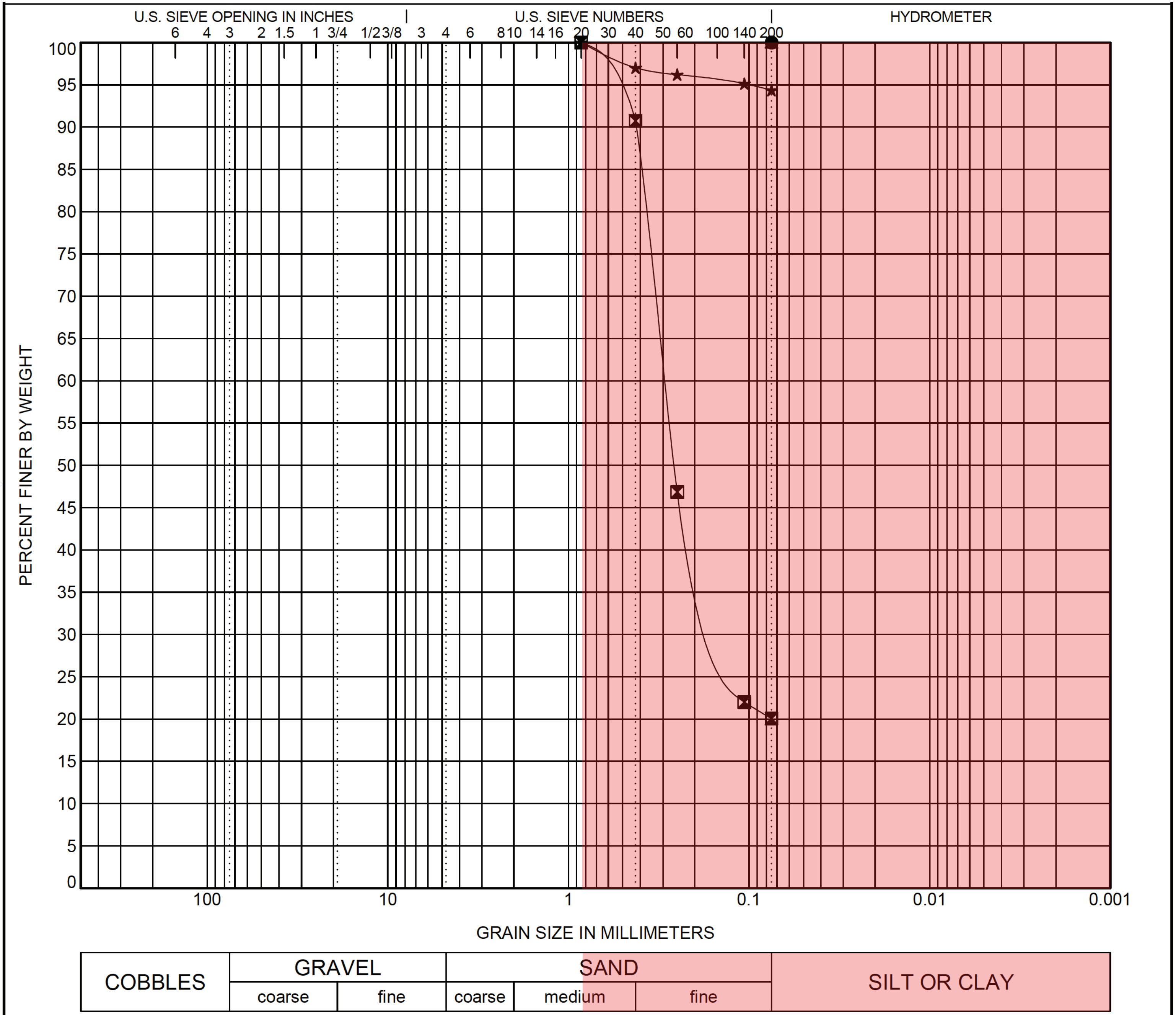
SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
● BWP-13	54-56	CLAYEY SAND(SC)	38	22	16		
⊠ BWP-13	74-76	SILTY SAND(SM)	NP	NP	NP		
▲ BWP-13	104-106	SILTY SAND(SM)	NP	NP	NP		
★ BWP-13	129-131	SILTY SAND(SM)	NP	NP	NP		
⊙ BWP-13	164-166	SILTY SAND(SM)	NP	NP	NP		

SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● BWP-13	54-56	4.75	0.261			1.2	54.5	44.3	
⊠ BWP-13	74-76	2	0.257			0.0	69.6	30.4	
▲ BWP-13	104-106	0.85	0.255	0.114		0.0	73.9	26.1	
★ BWP-13	129-131	19	0.513	0.264		5.4	76.5	18.1	
⊙ BWP-13	164-166	2	0.15			0.0	51.2	48.8	



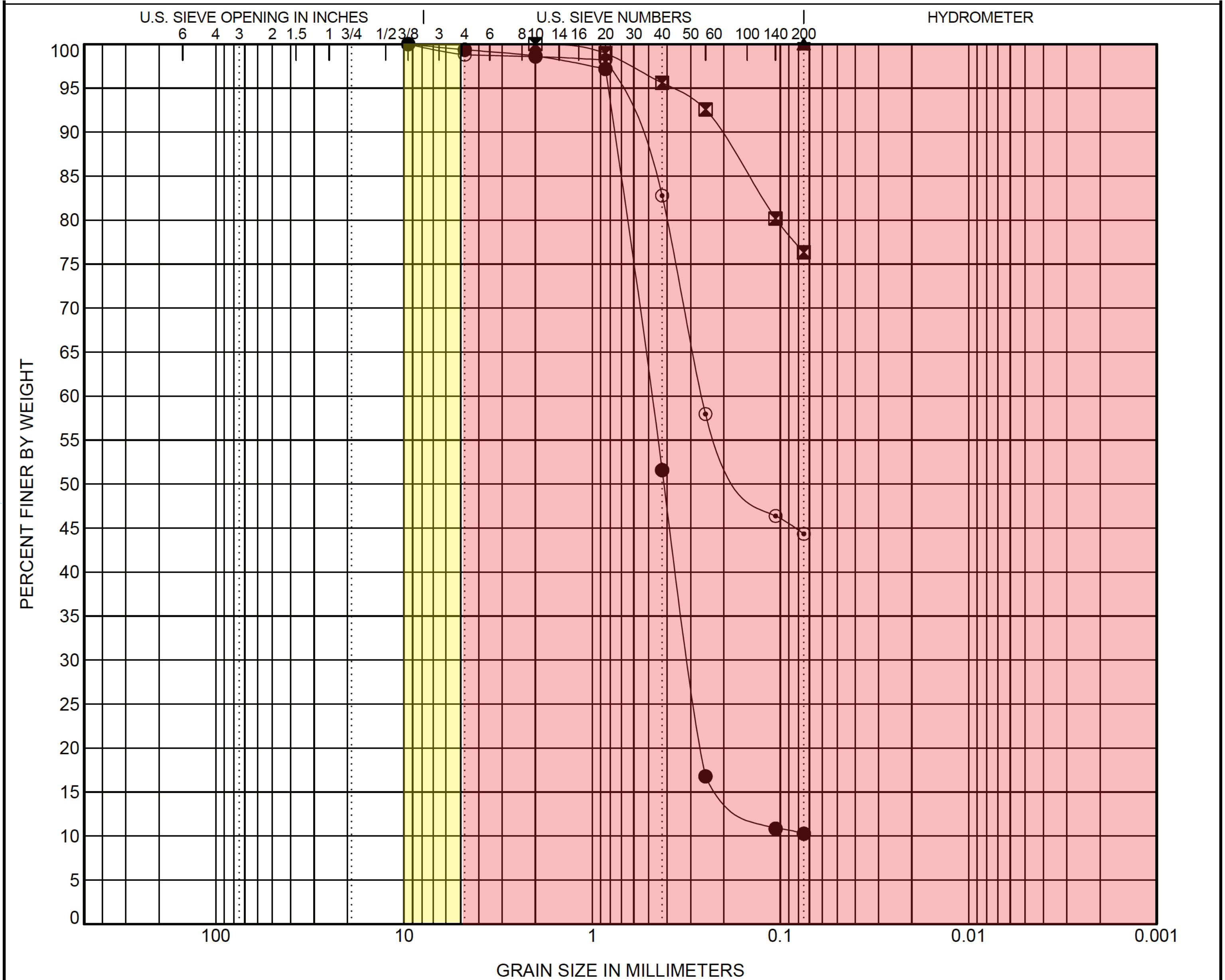
SAMPLE No.		DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-13**	**179-181**	**LEAN CLAY(CL)**	**29**	**18**	**11**		
⊠	**BWP-16**	**40-41.5**	**LEAN CLAY(CL)**	**30**	**18**	**12**		
▲	**BWP-16**	**65-66.5**	**SILT(ML)**	**36**	**27**	**9**		
★	**BWP-16**	**95-96.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
⊙	**BWP-16**	**115-116.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		

SAMPLE No.		DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-13**	**179-181**								
⊠	**BWP-16**	**40-41.5**								
▲	**BWP-16**	**65-66.5**								
★	**BWP-16**	**95-96.5**	**4.75**	**0.508**	**0.278**		**0.0**	**84.8**	**15.2**	
⊙	**BWP-16**	**115-116.5**	**0.85**	**0.158**			**0.0**	**55.3**	**44.7**	



	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-16**	**127-128.5**	**SILT(ML)**	**35**	**26**	**9**		
⊠	**BWP-16**	**155-156.5**	**SILTY SAND(SM)**	**NP**	**NP**	**NP**		
▲	**BWP-16**	**165-166.5**	**SILT(ML)**	**36**	**27**	**9**		
★	**BWP-16**	**210-211.5**	**LEAN CLAY(CL)**	**44**	**21**	**23**		
⊙	**BWP-18**	**30-31.5**	**LEAN CLAY(CL)**	**41**	**23**	**18**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-16**	**127-128.5**								
⊠	**BWP-16**	**155-156.5**	**0.85**	**0.293**	**0.14**		**0.0**	**79.9**	**20.1**	
▲	**BWP-16**	**165-166.5**								
★	**BWP-16**	**210-211.5**	**0.85**				**0.0**	**5.6**	**94.4**	
⊙	**BWP-18**	**30-31.5**								

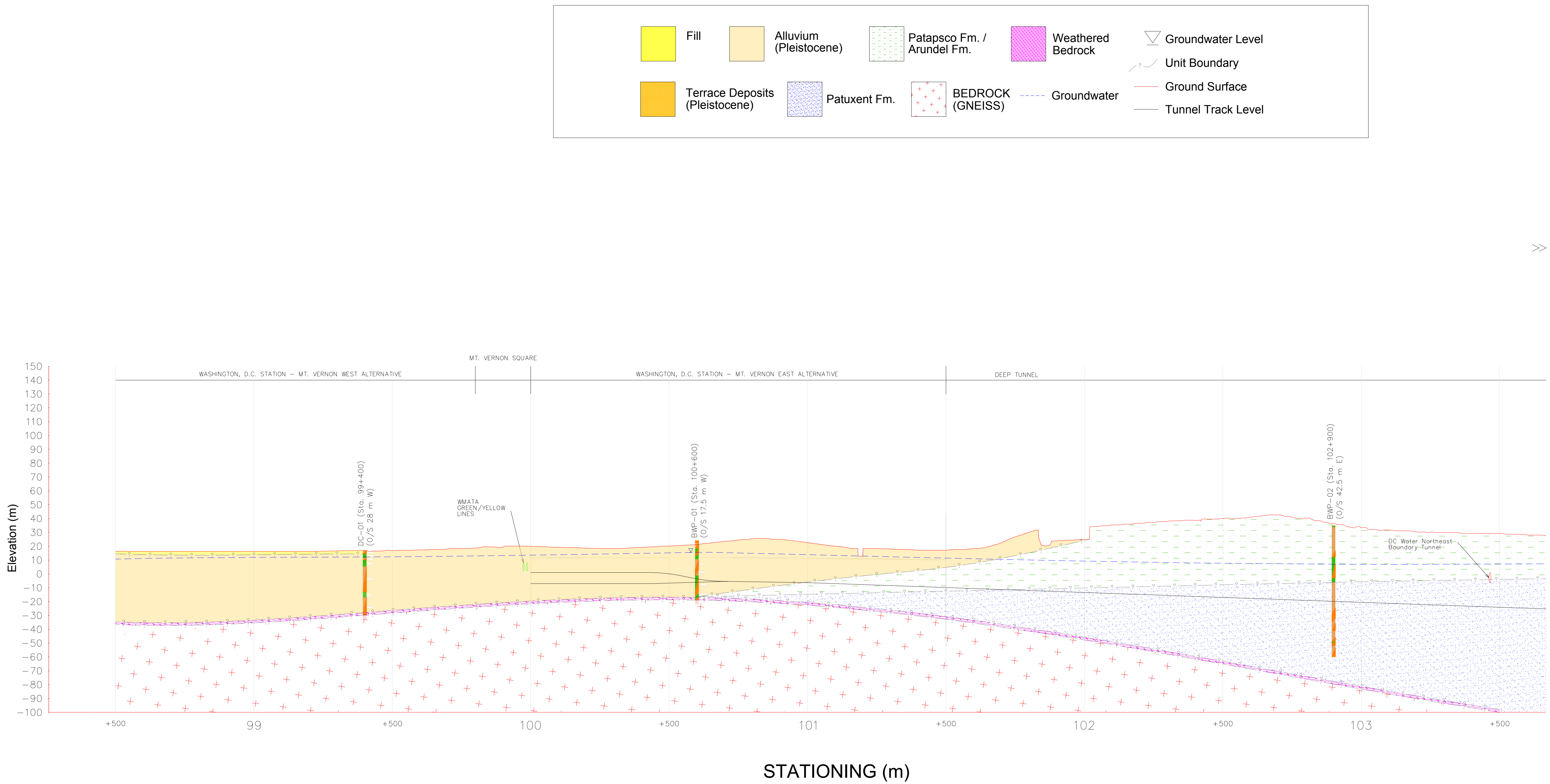


COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	SAMPLE No.	DEPTH(ft)	Classification	LL	PL	PI	Cc	Cu
●	**BWP-18**	**70-71.5**	**POORLY GRADED SAND with SILT(SP-SM)**	**NP**	**NP**	**NP**	**3.04**	**7.58**
⊠	**BWP-18**	**100-101.5**	**LEAN CLAY with SAND(CL)**	**33**	**20**	**13**		
▲	**BWP-18**	**110-111.5**	**LEAN CLAY(CL)**	**37**	**23**	**14**		
★	**BWP-18**	**140-141.5**	**SILT(ML)**	**35**	**27**	**8**		
⊙	**BWP-18**	**156-158**	**CLAYEY SAND(SC)**	**34**	**19**	**15**		

	SAMPLE No.	DEPTH(ft)	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BWP-18**	**70-71.5**	**9.5**	**0.483**	**0.306**		**0.6**	**89.1**	**10.3**	
⊠	**BWP-18**	**100-101.5**	**2**				**0.0**	**23.7**	**76.3**	
▲	**BWP-18**	**110-111.5**								
★	**BWP-18**	**140-141.5**								
⊙	**BWP-18**	**156-158**	**9.5**	**0.261**			**1.2**	**54.5**	**44.3**	

APPENDIX C: GENERALIZED GEOLOGICAL PROFILES WITH RESPECT TO ALIGNMENTS



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DRAWN: TO
CHECKED: KT
APPROVED: VG

PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

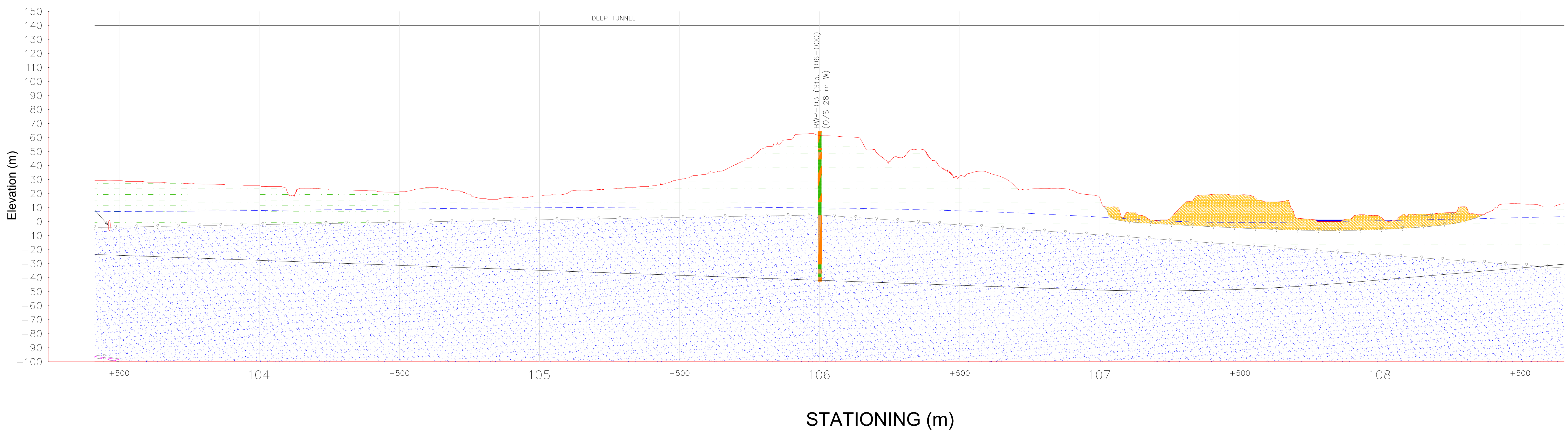
DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 98+500 TO STATION 103+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-01
REV: 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 1 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater | Tunnel Track Level

<< >>



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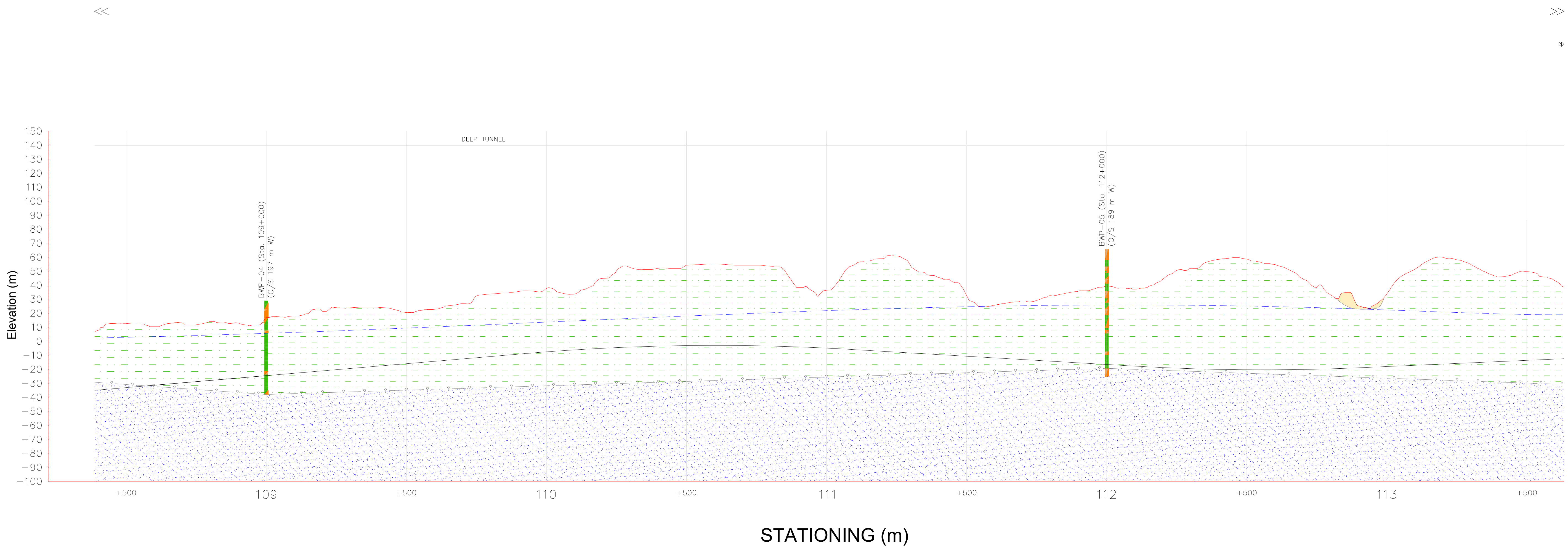
PROJECT No.: 0661 BWMLV

DRAWING TITLE:

GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 103+500 TO STATION 108+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-02 REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 2 OF 12

Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater
Ground Surface
Tunnel Track Level



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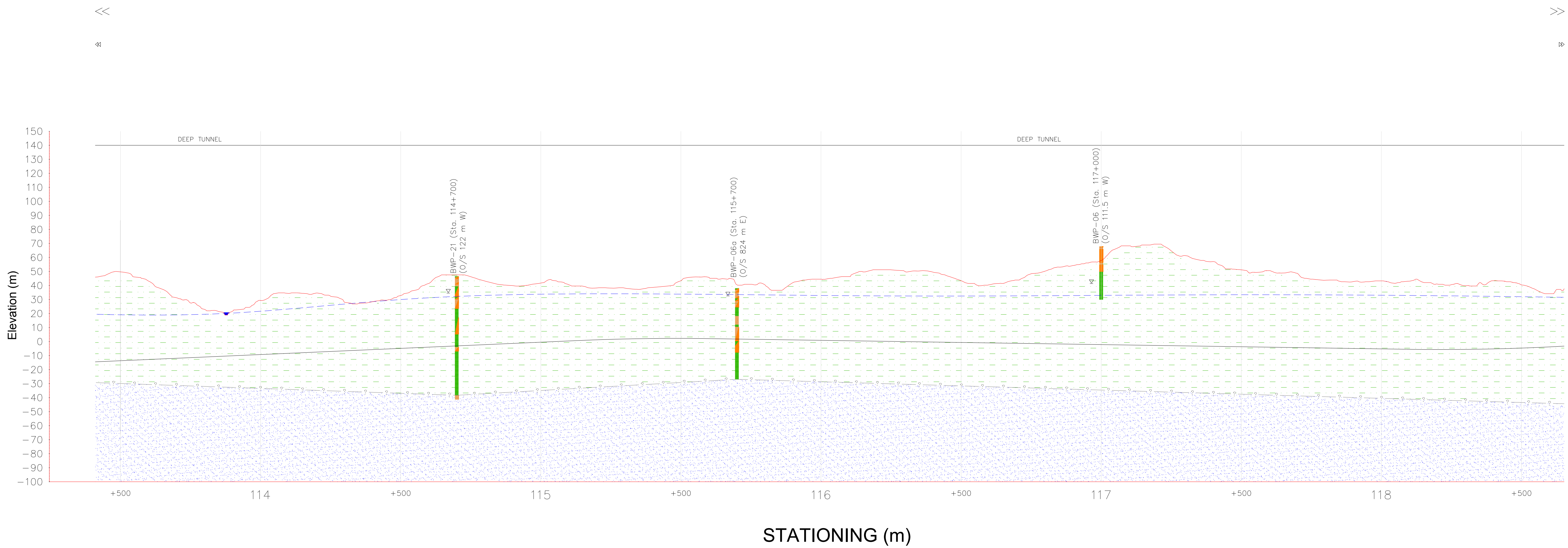
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 108+500 TO STATION 113+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-03
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 3 OF 12

- Fill
- Alluvium (Pleistocene)
- Patapsco Fm. / Arundel Fm.
- Weathered Bedrock
- Groundwater Level
- Unit Boundary
- Ground Surface
- Terrace Deposits (Pleistocene)
- Patuxent Fm.
- BEDROCK (GNEISS)
- Groundwater
- Tunnel Track Level



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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 113+500 TO STATION 118+500

SCALE:
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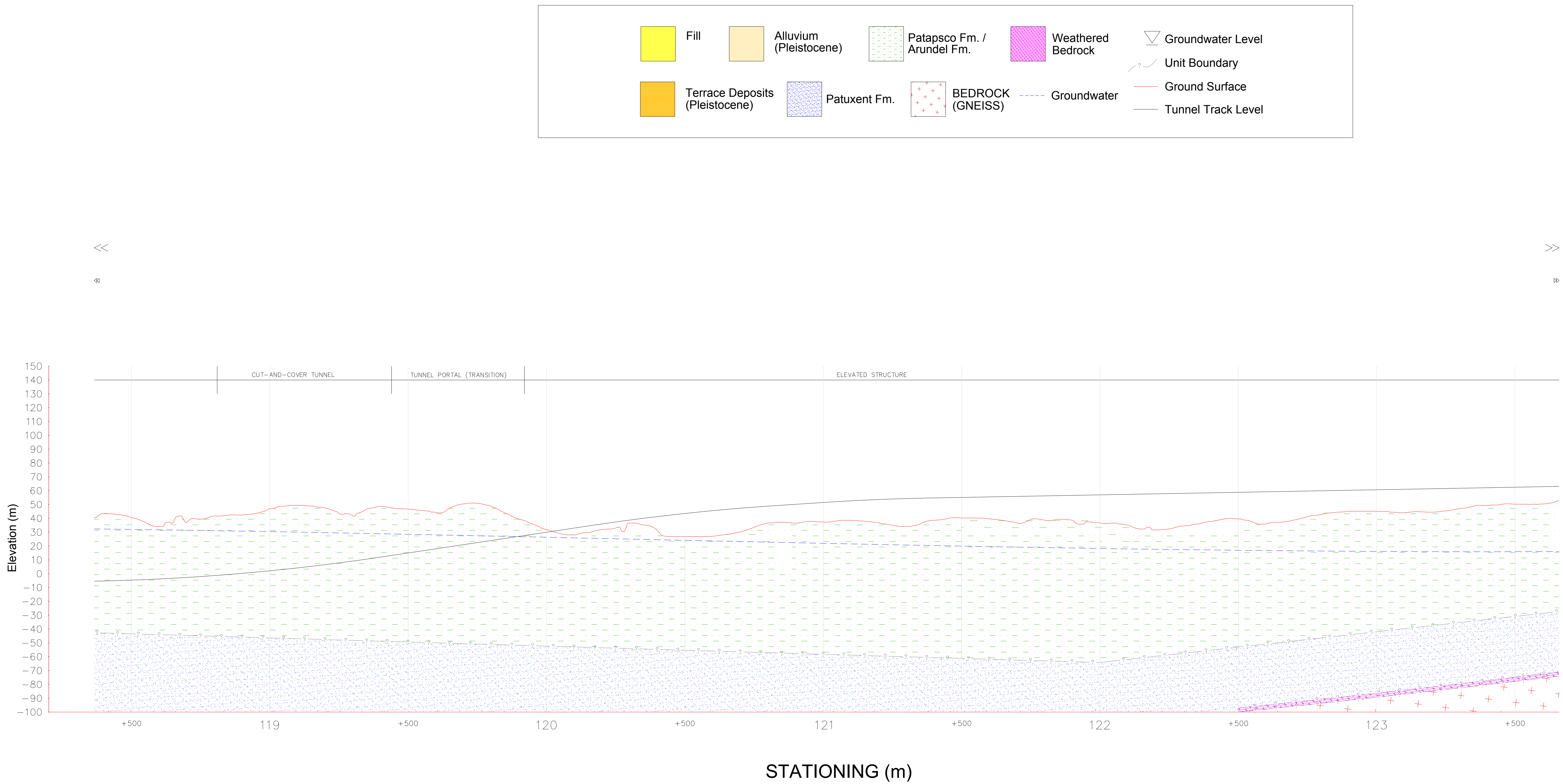
DRAWING No.: GP-04
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 4 OF 12



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APPROVED: VG

PROJECT NAME:
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ADVISORY SERVICES CONTRACT

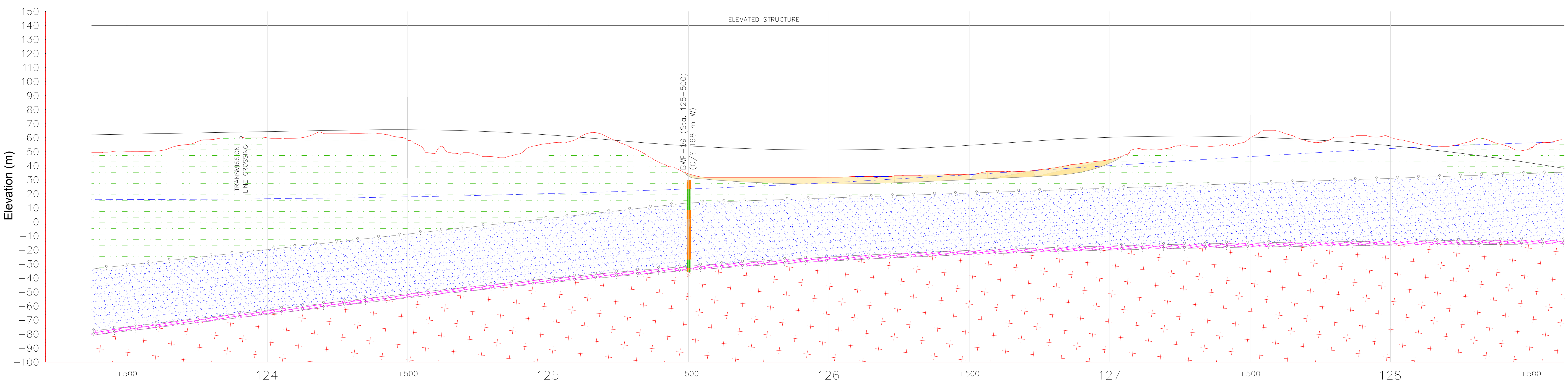
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 118+500 TO STATION 123+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-05
REV: 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 5 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface | Tunnel Track Level

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater



STATIONING (m)

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PROJECT NAME:
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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 123+500 TO STATION 128+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-06
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 6 OF 12

Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Ground Surface

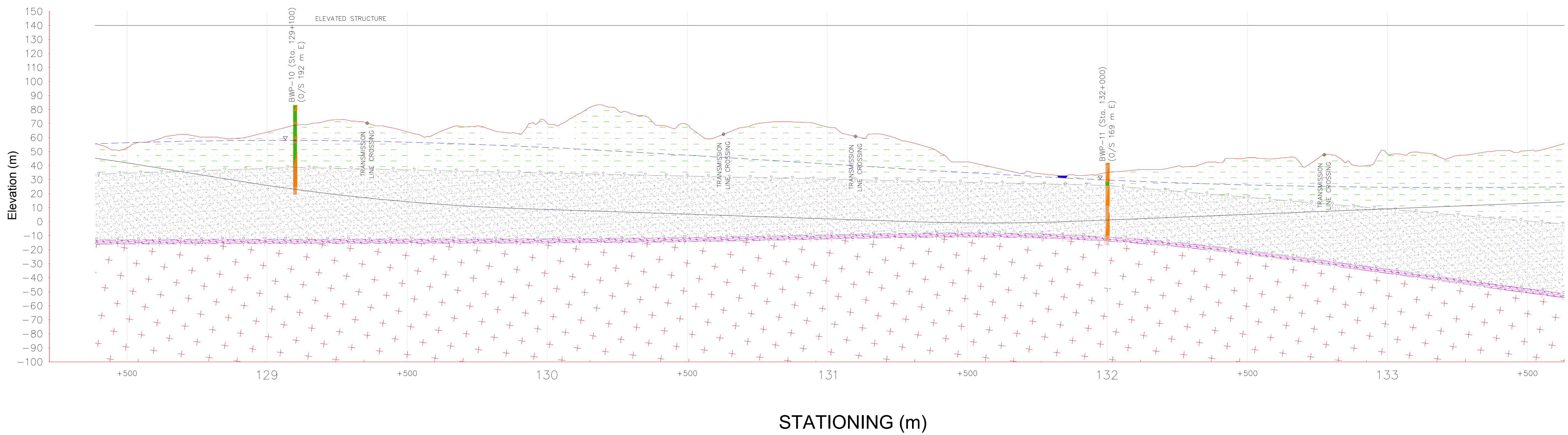
Terrace Deposits (Pleistocene)

Patuxent Fm.

BEDROCK (GNEISS)

Groundwater

Tunnel Track Level



DATE	REVISIONS	No

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APPROVED: VG

PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 128+500 TO STATION 133+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-07
REV: 0
DATE: 12/04/2018

CONTR. No.
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SHEET No. 7 OF 12

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Fill

Alluvium (Pleistocene)

Patapsco Fm. / Arundel Fm.

Weathered Bedrock

Groundwater Level

Unit Boundary

Ground Surface

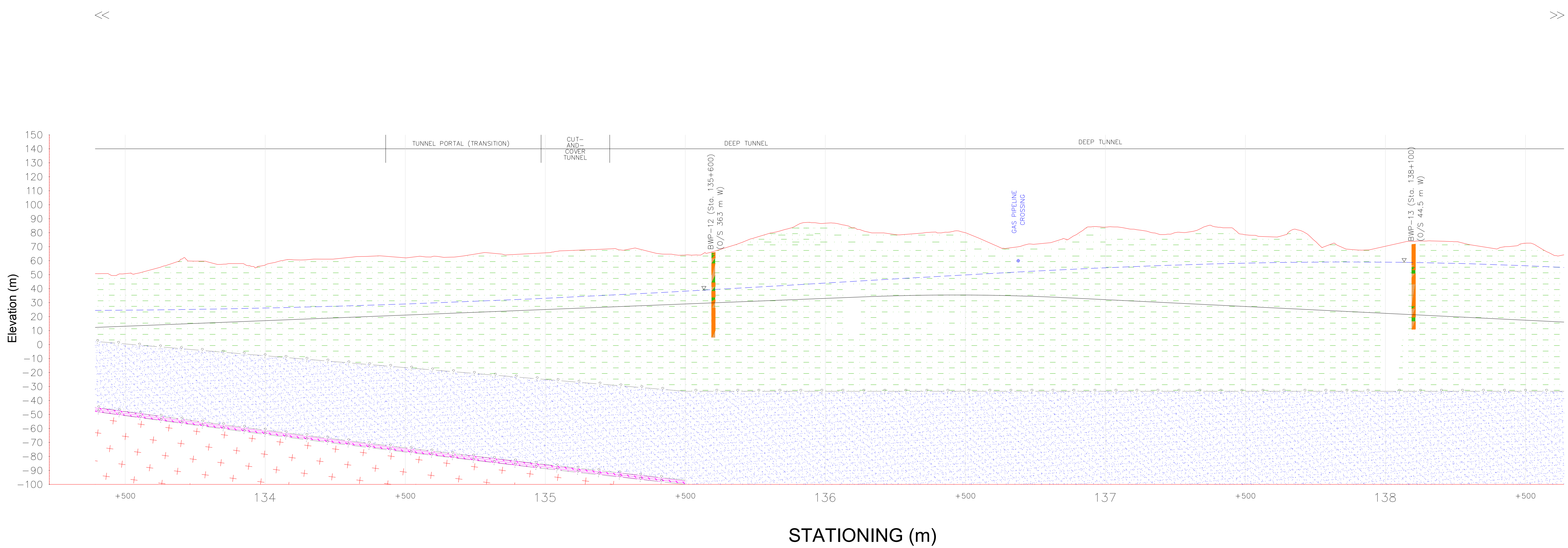
Tunnel Track Level

Terrace Deposits (Pleistocene)

Patuxent Fm.

BEDROCK (GNEISS)

Groundwater



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PROJECT NAME:
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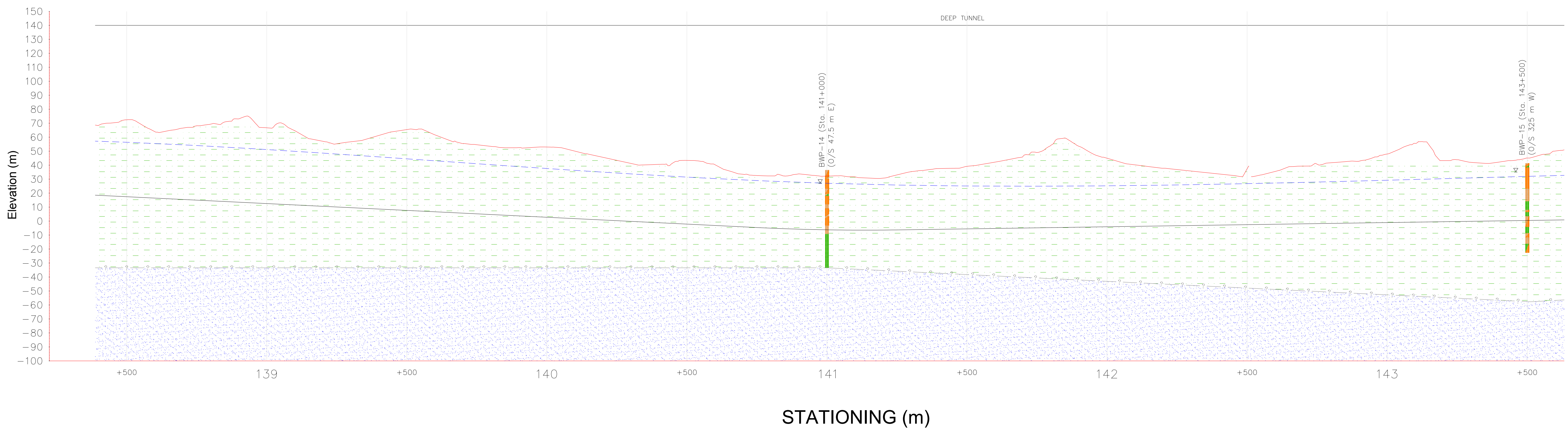
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 133+500 TO STATION 138+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-08
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 8 OF 12

Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater



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SCALE:	CONTR. No.
FILE NAME: 0661 BWMLV	ISSUE
DRAWING No.: GP-09 / REV 0	
DATE: 12/04/2018	SHEET No. 9 OF 12

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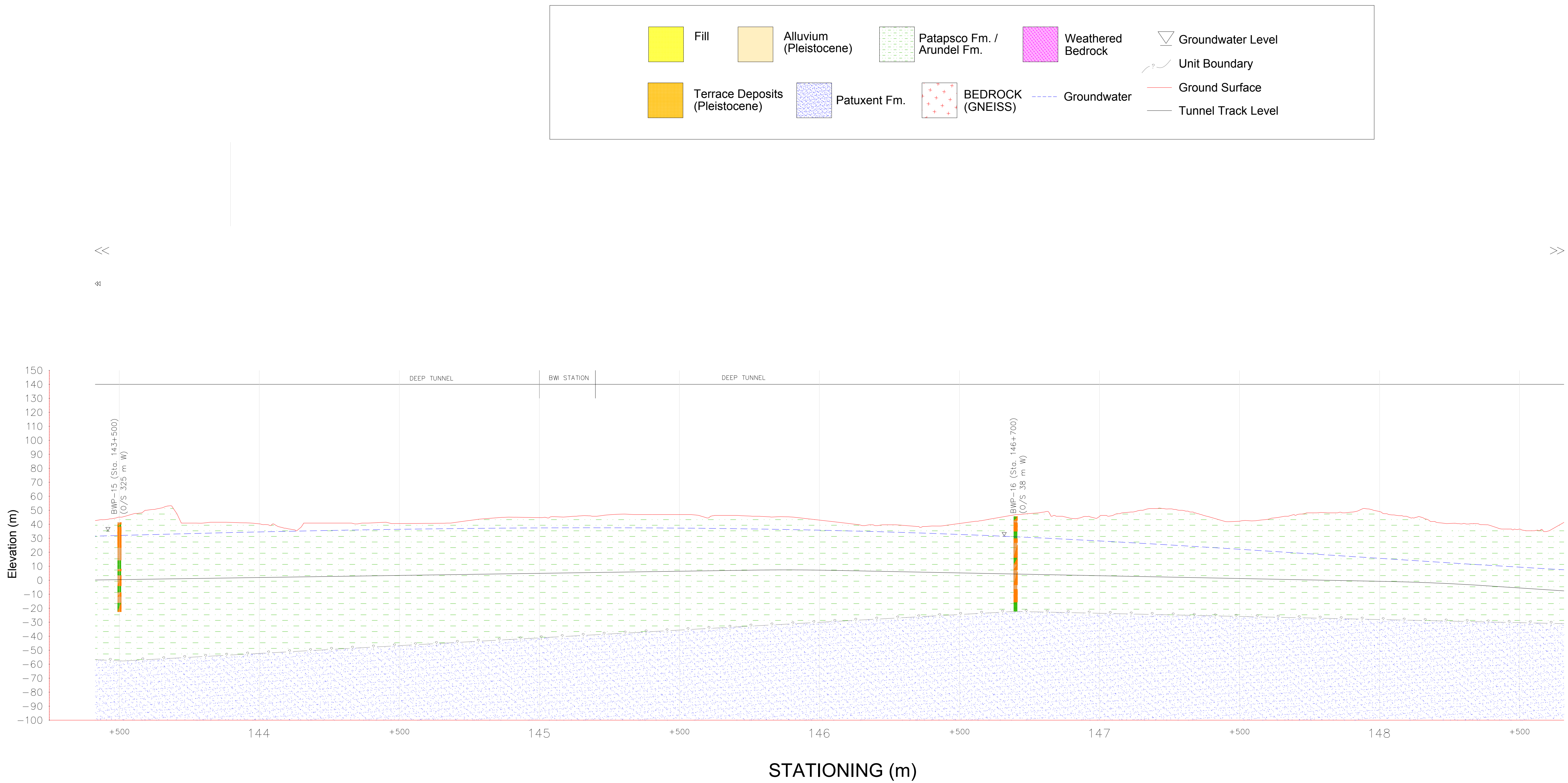

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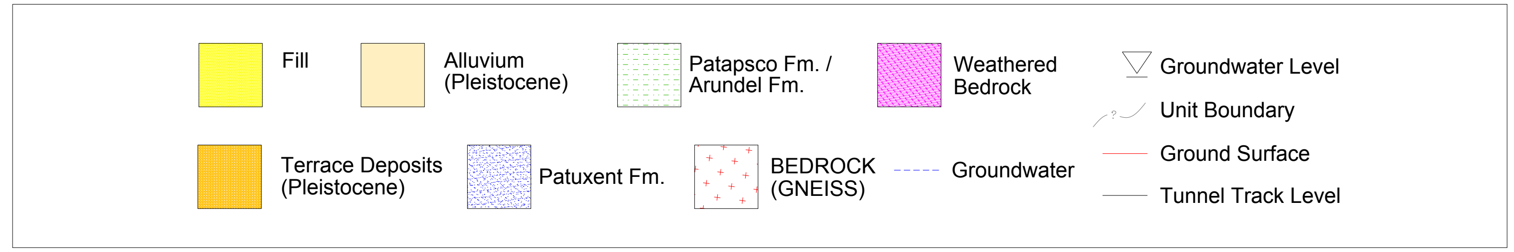
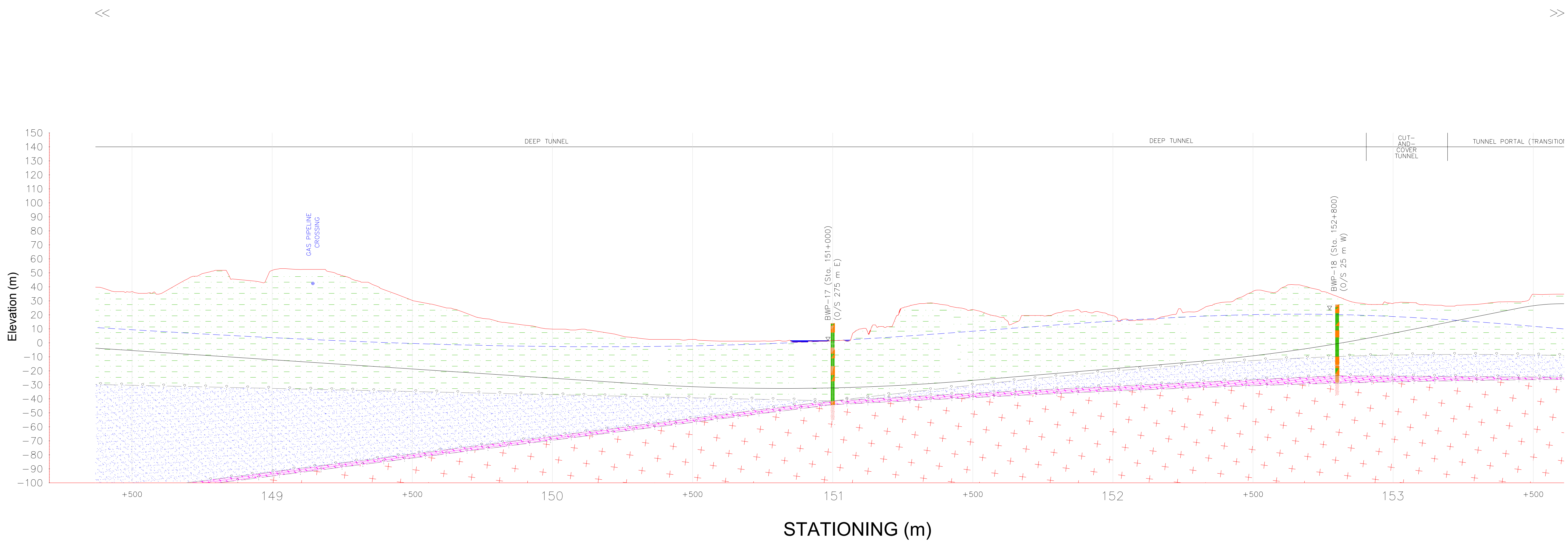
SCALE:	CONTR. No.
FILE NAME: 0661 BWMLV	ISSUE
DRAWING No.: GP-10 / REV 0	SHEET No. 10 OF 12
DATE: 12/04/2018	





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DRAWN: TO			FILE NAME: 0661 BWMLV	ISSUE
CHECKED: KT			DRAWING No.: GP-11 REV 0	
APPROVED: VG	PROJECT No.: 0661 BWMLV		DATE: 12/04/2018	SHEET No. 11 OF 12

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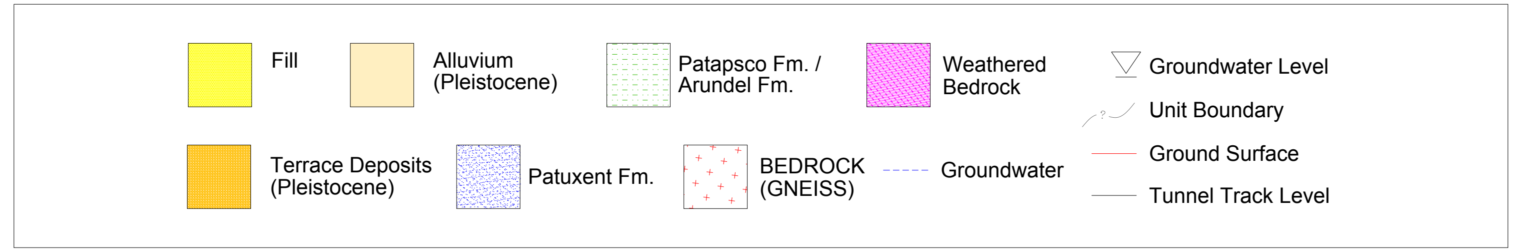

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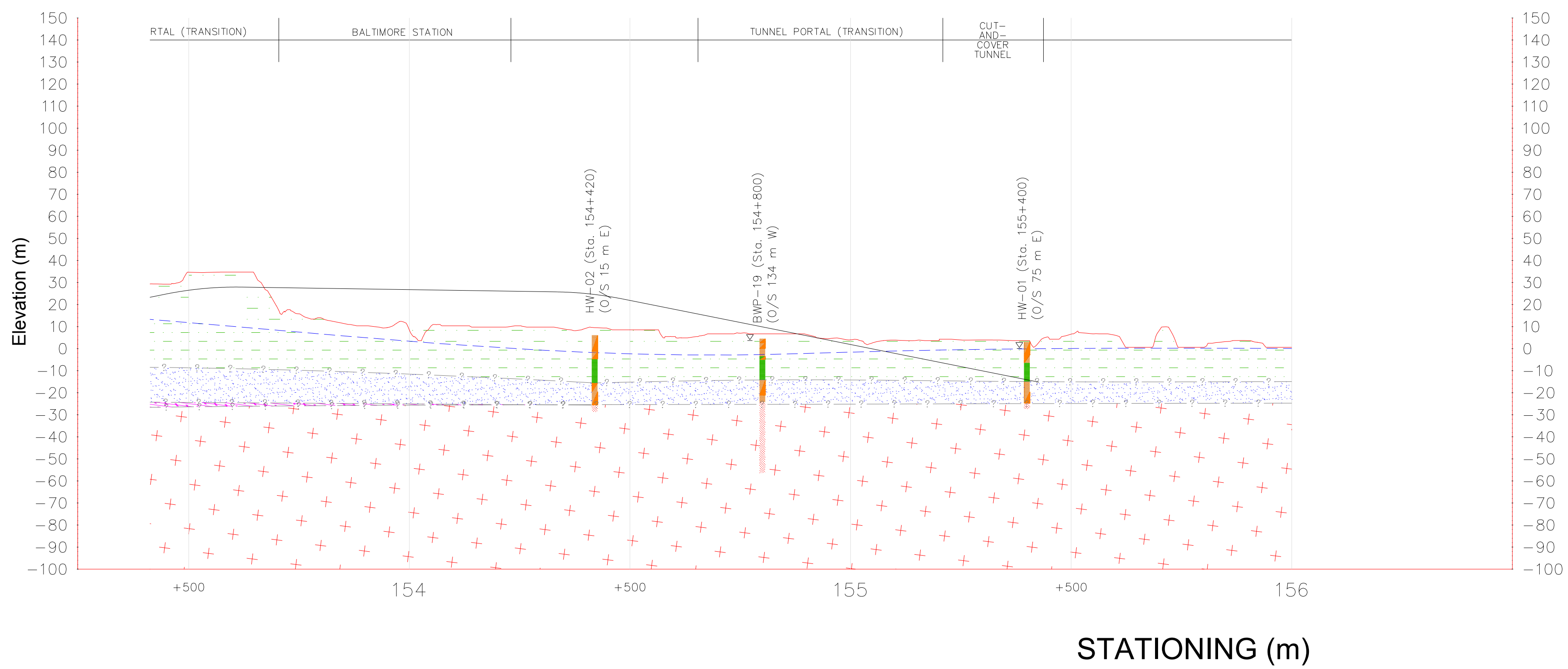

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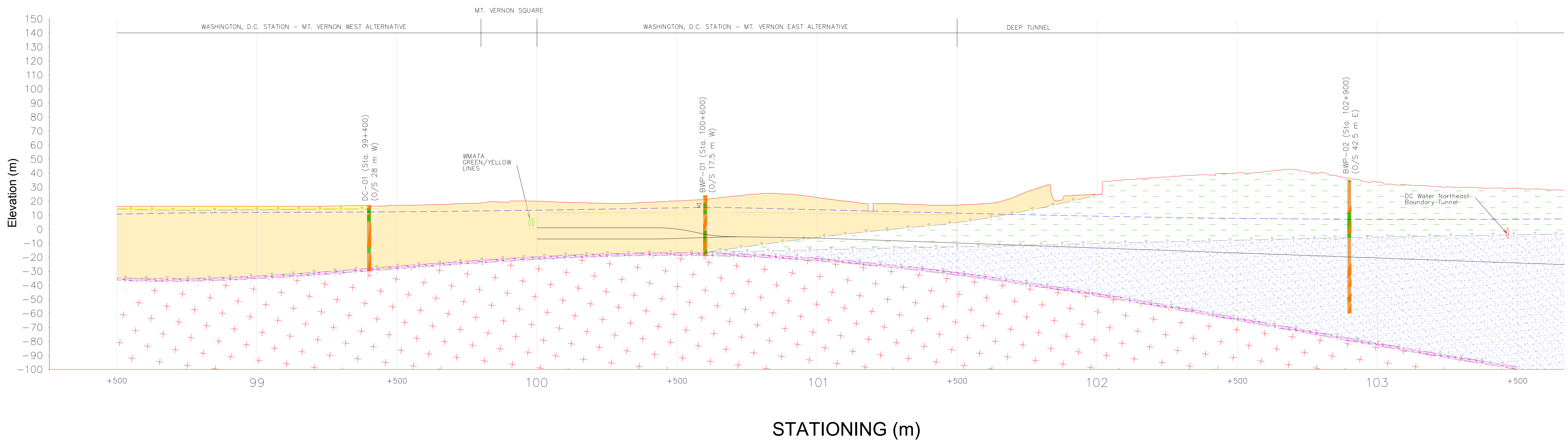
PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J1 OPTION 5
STATION 153+500 TO STATION 156+000

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-12
REV: 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 12 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface | Tunnel Track Level

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater



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DRAWN: TO			FILE NAME: 0661 BWMLV
CHECKED: KT			DRAWING No.: GP-13 REV 0
APPROVED: VG	PROJECT No.: 0661 BWMLV		DATE: 12/04/2018

DATE | REVISIONS | No

CONTR. No. | ISSUE | SHEET No. 1 OF 12

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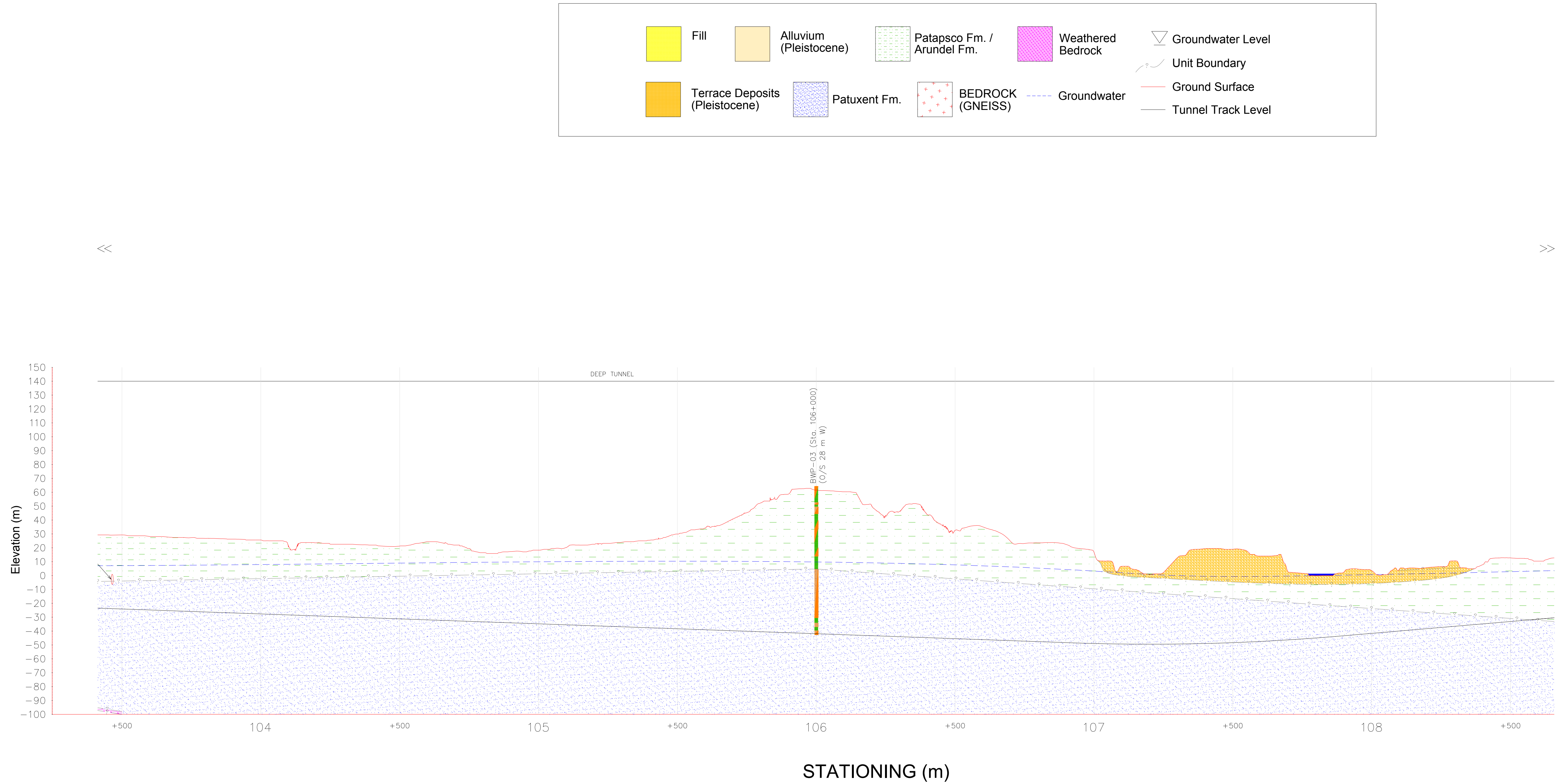

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DRAWN: TO		
CHECKED: KT		
APPROVED: VG	PROJECT No.: 0661 BWMLV	

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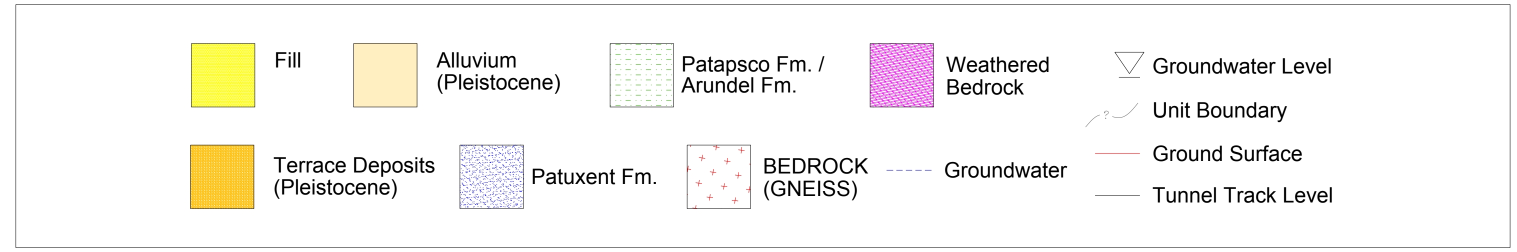
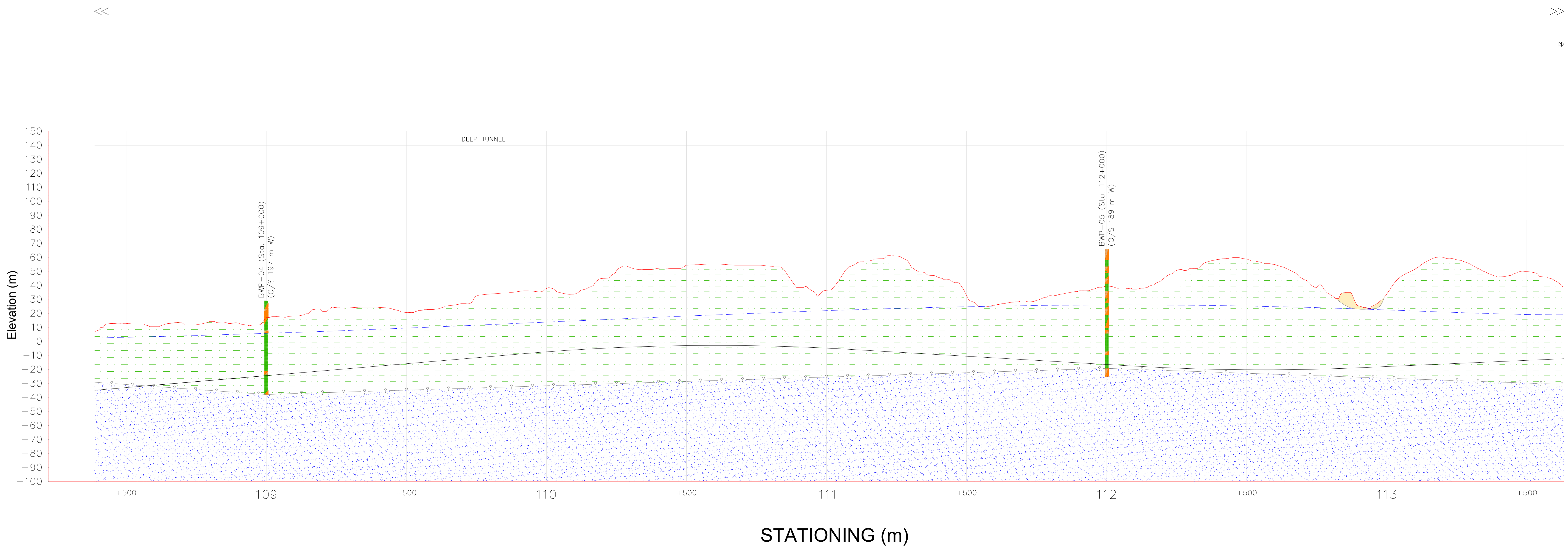
SCALE:
CONTR. No.
FILE NAME: 0661 BWMLV
ISSUE
DRAWING No.: GP-014
REV 0
DATE: 12/04/2018
SHEET No. 2 OF 12





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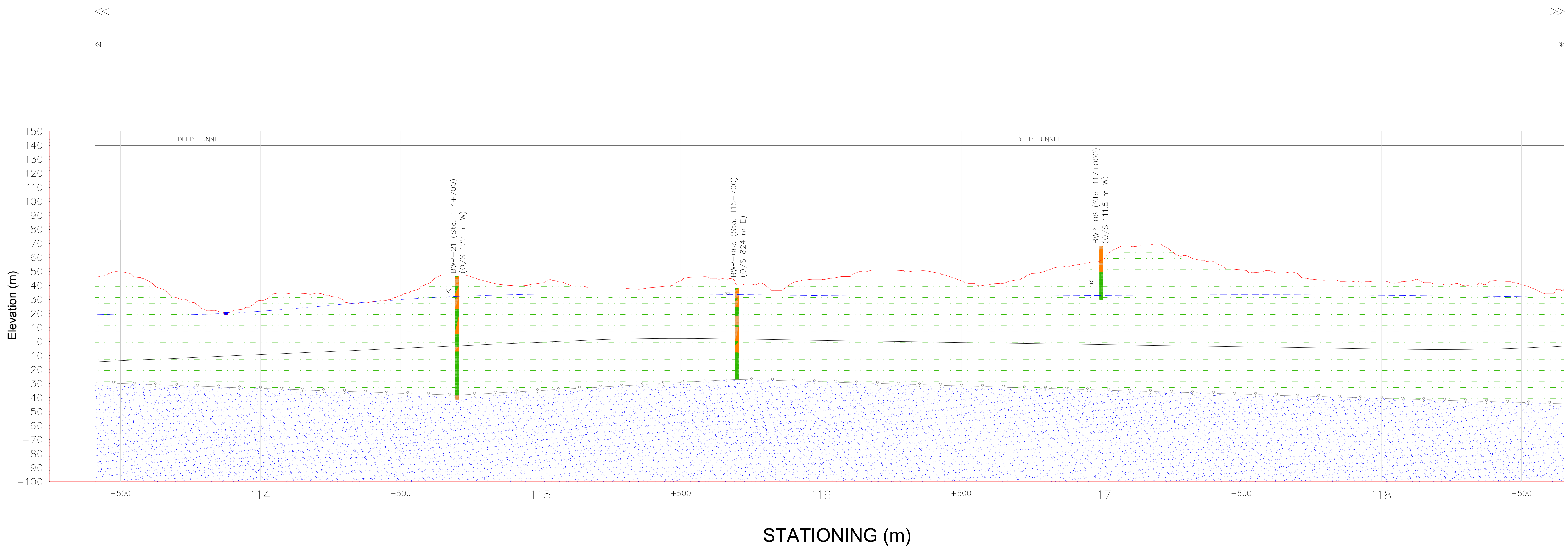
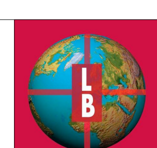
SCALE:	CONTR. No.	FILE NAME: 0661 BWMLV	ISSUE	
DRAWING No.: GP-15	REV 0	DATE: 12/04/2018	SHEET No. 3 OF 12	

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface | Tunnel Track Level

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater





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APPROVED: VG

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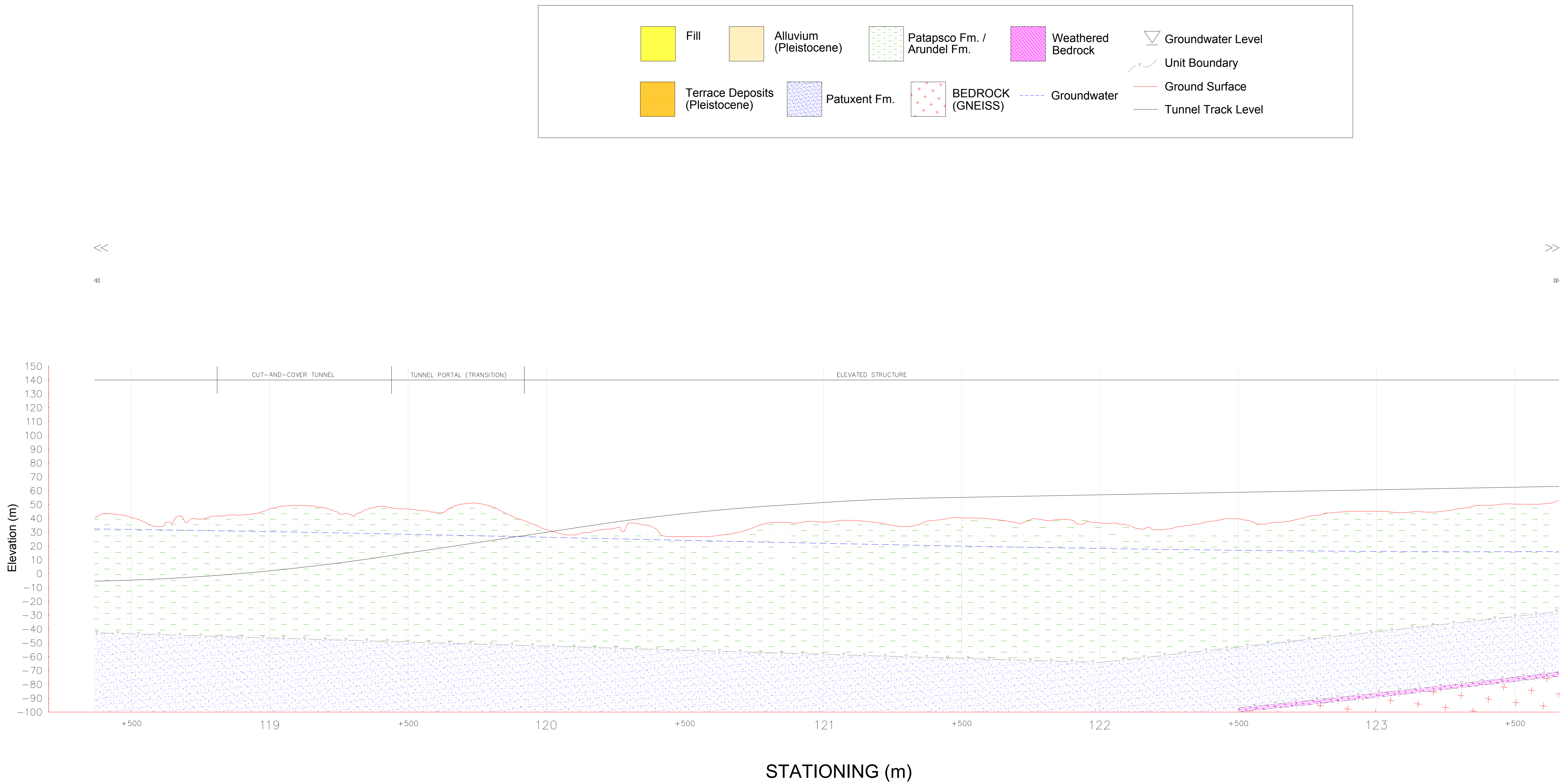
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 113+500 TO STATION 118+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-16
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 4 OF 12



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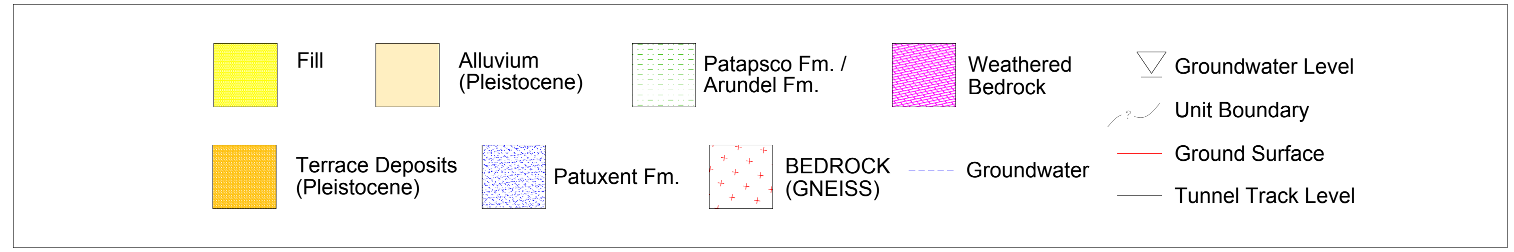

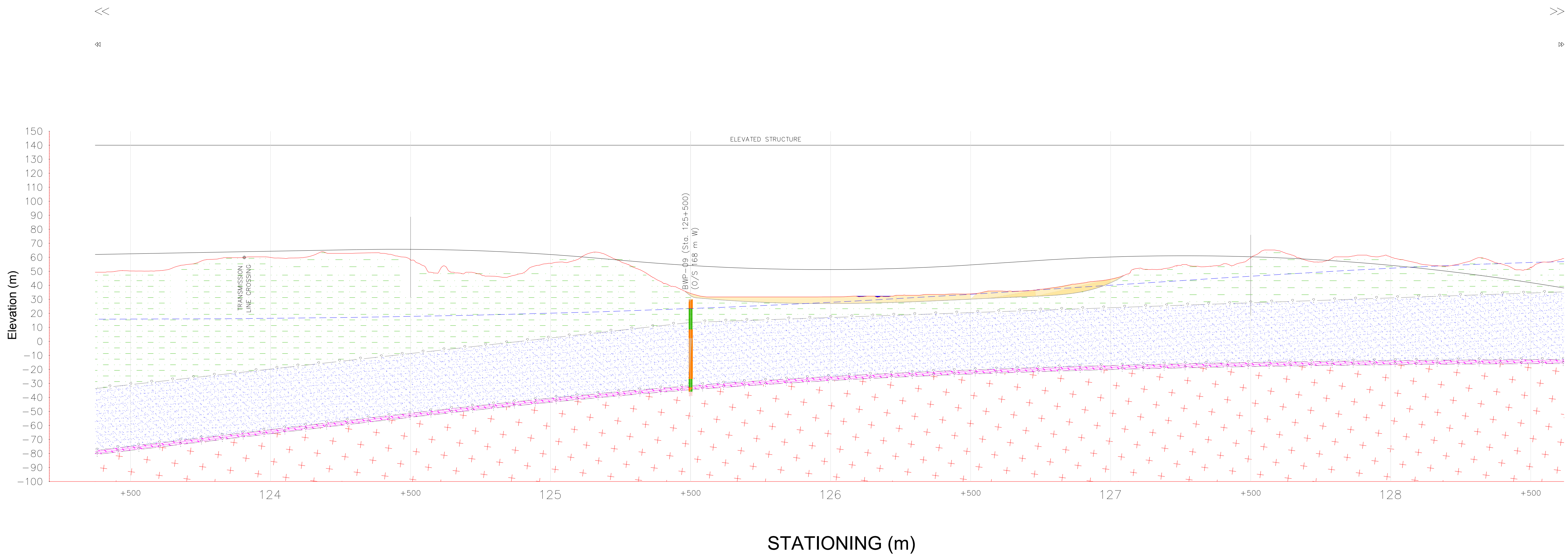

DATE	REVISIONS	No	
DESIGNED: TO	DRAWN: TO	CHECKED: KT	APPROVED: VG

PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 123+500 TO STATION 128+500

SCALE:
CONTR. No.
FILE NAME: 0661 BWMLV
ISSUE
DRAWING No.: GP-18
REV 0
DATE: 12/04/2018
SHEET No. 6 OF 12

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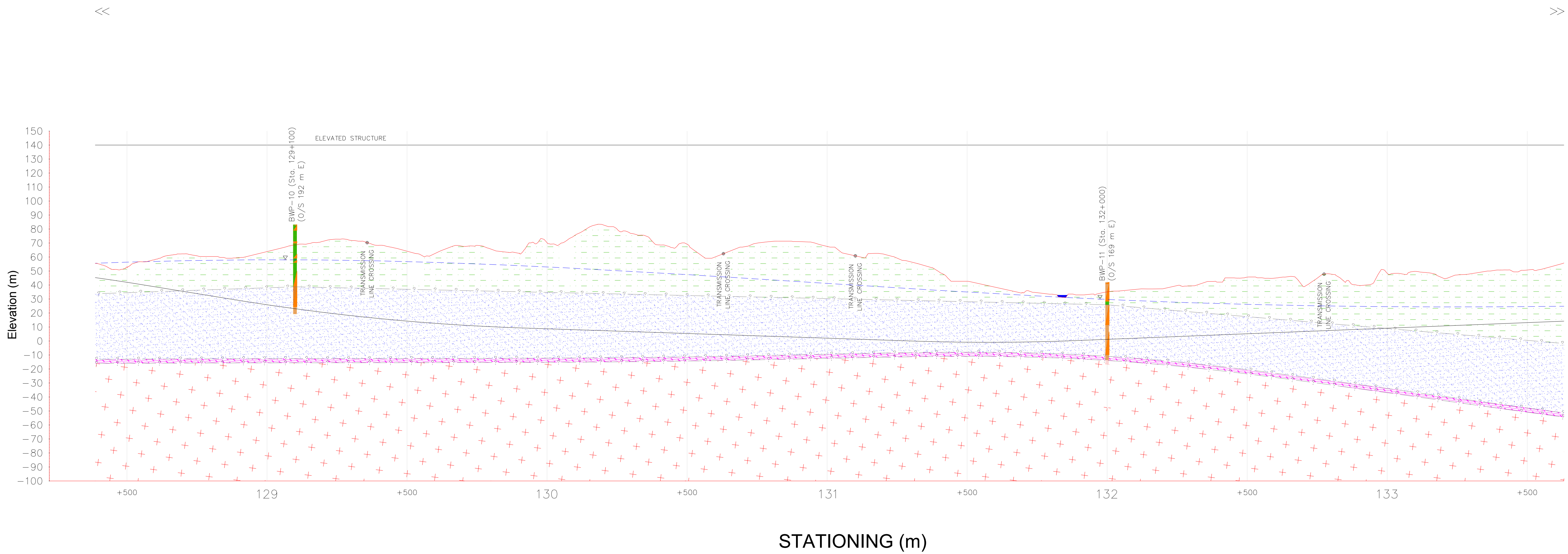
Fill
Alluvium (Pleistocene)
Patapsco Fm. / Arundel Fm.
Weathered Bedrock
Groundwater Level
Unit Boundary
Ground Surface
Tunnel Track Level
Terrace Deposits (Pleistocene)
Patuxent Fm.
BEDROCK (GNEISS)
Groundwater



DATE	REVISIONS	No

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DRAWN: TO
CHECKED: KT
APPROVED: VG

PROJECT NAME:
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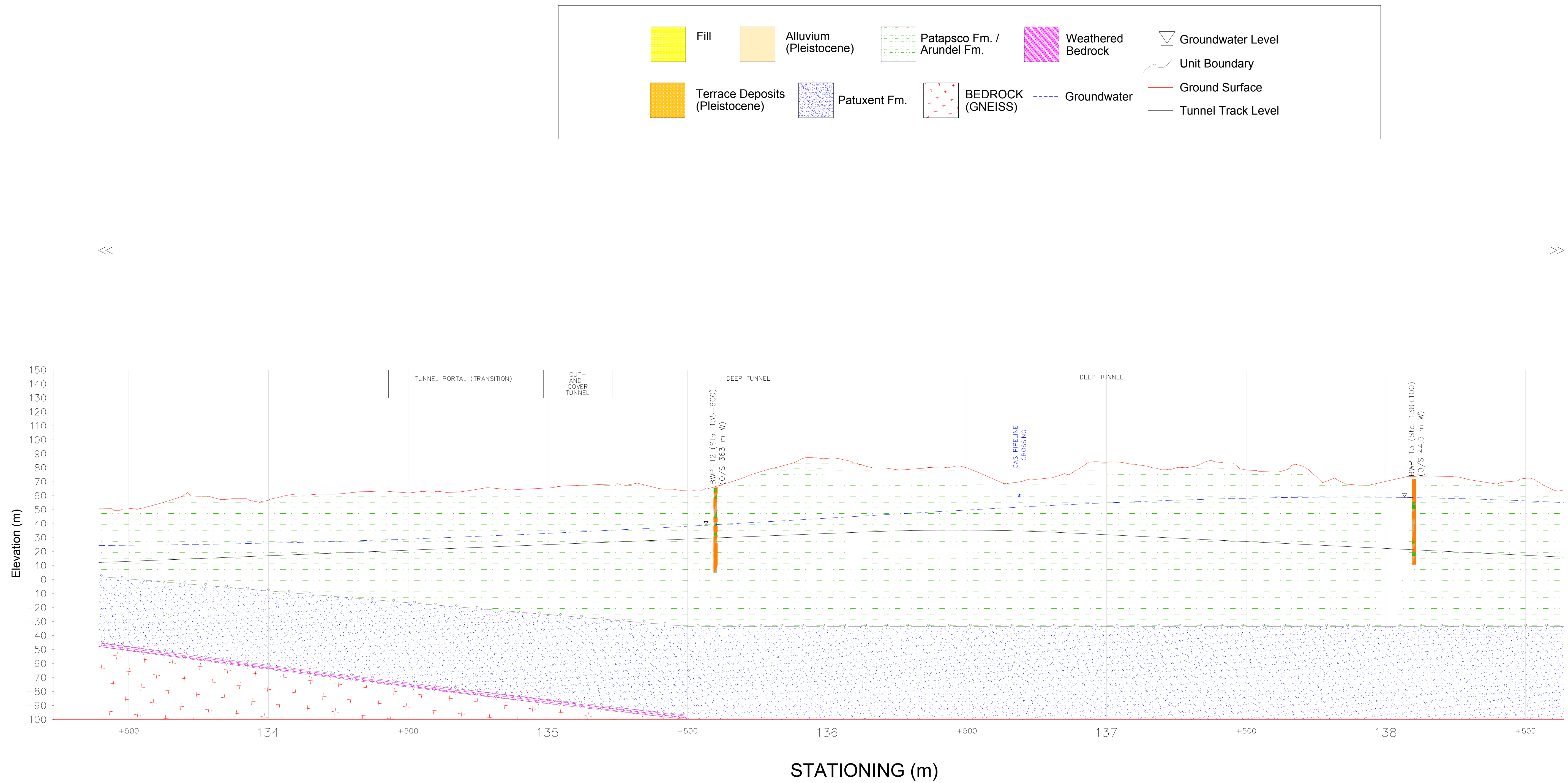
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT OPTION J MODIFIED 1
STATION 128+500 TO STATION 133+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-19
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 7 OF 12



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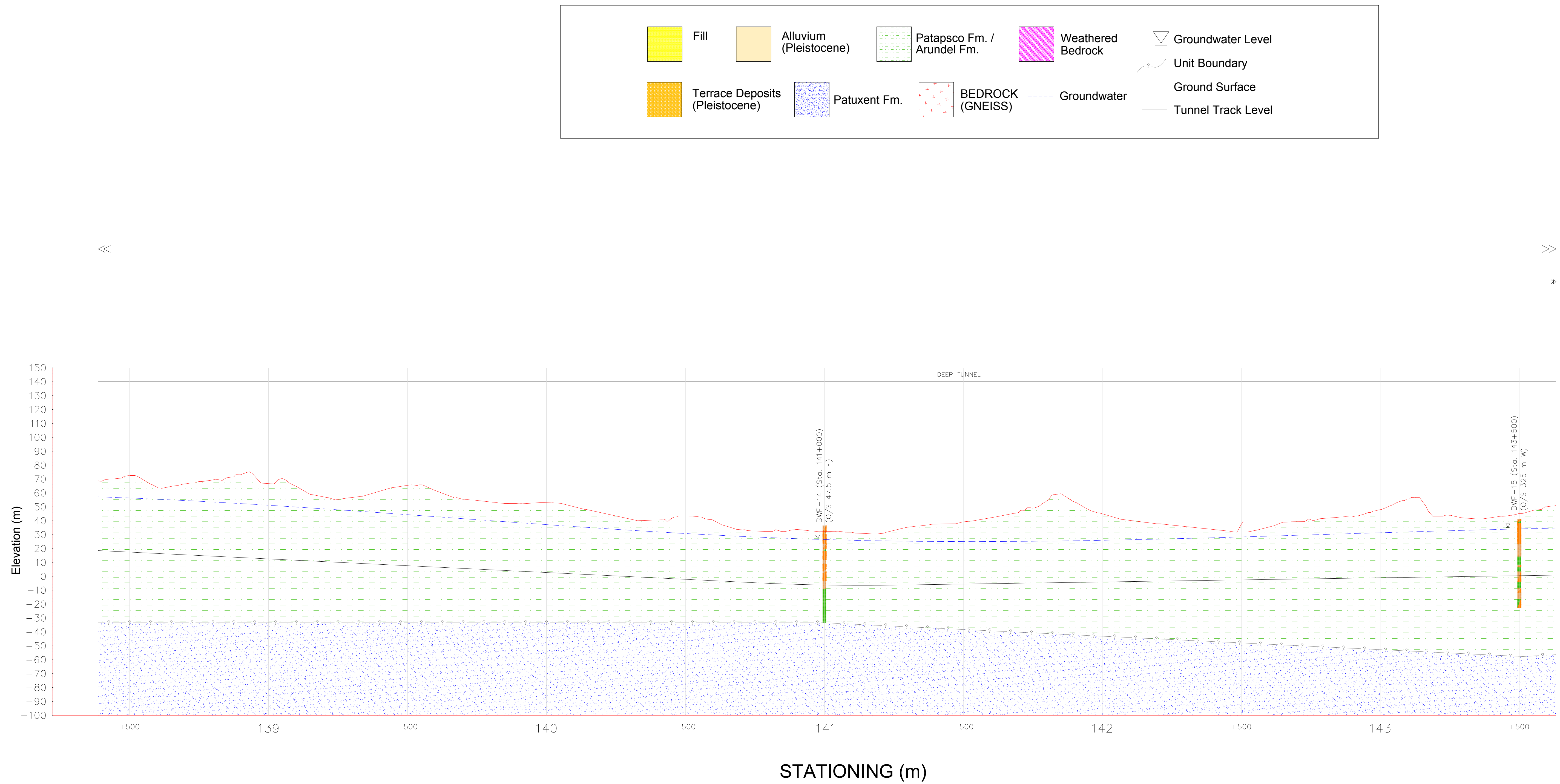
DATE: 12/04/2018	SHEET No. 8 OF 12			



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PROJECT NAME:
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ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 138+500 TO STATION 143+500

SCALE:
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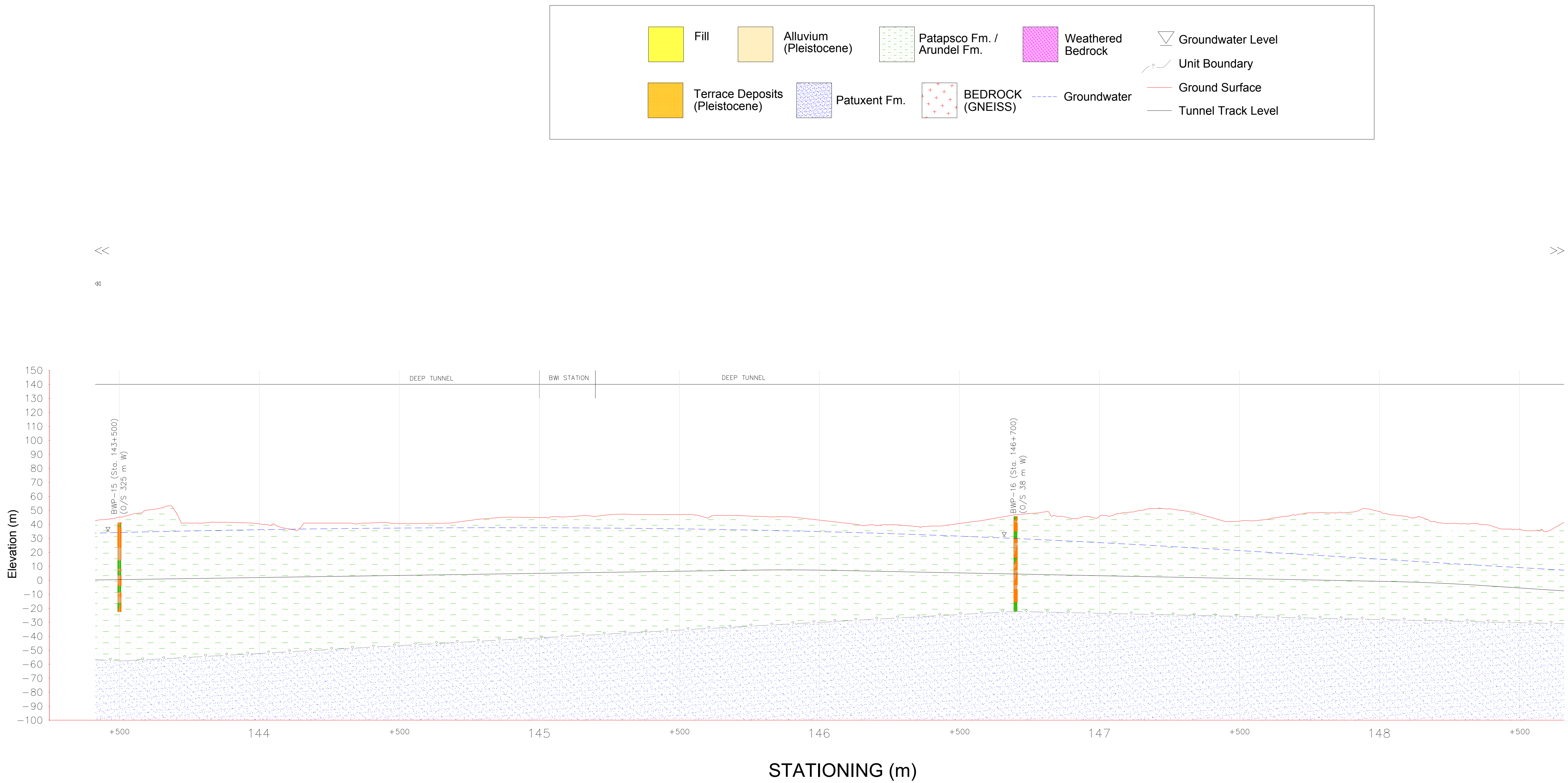
DRAWING No.: GP-21
REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 9 OF 12



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DRAWN: TO			FILE NAME: 0661 BWMLV
CHECKED: KT			DRAWING No.: GP-22 REV 0
APPROVED: VG	PROJECT No.: 0661 BWMLV		DATE: 12/04/2018

CONTR. No.

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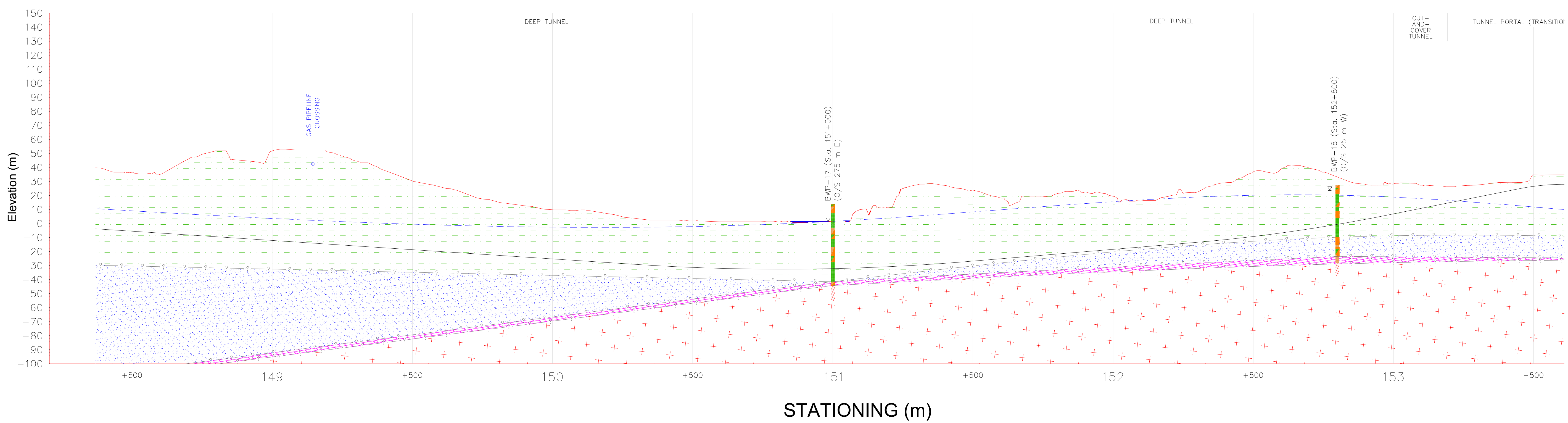
Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface
Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater | Tunnel Track Level



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PROJECT NAME:
BALTIMORE-WASHINGTON SCMAGLEV PROJECT
ADVISORY SERVICES CONTRACT

PROJECT No.: 0661 BWMLV

DRAWING TITLE:
GEOLOGIC LONGITUDINAL SECTION
ALIGNMENT ALTERNATIVE J MODIFIED 1
STATION 148+500 TO STATION 153+500

SCALE:
FILE NAME: 0661 BWMLV
DRAWING No.: GP-23 REV 0
DATE: 12/04/2018
CONTR. No.
ISSUE
SHEET No. 11 OF 12

Fill | Alluvium (Pleistocene) | Patapsco Fm. / Arundel Fm. | Weathered Bedrock | Groundwater Level | Unit Boundary | Ground Surface | Tunnel Track Level

Terrace Deposits (Pleistocene) | Patuxent Fm. | BEDROCK (GNEISS) | Groundwater

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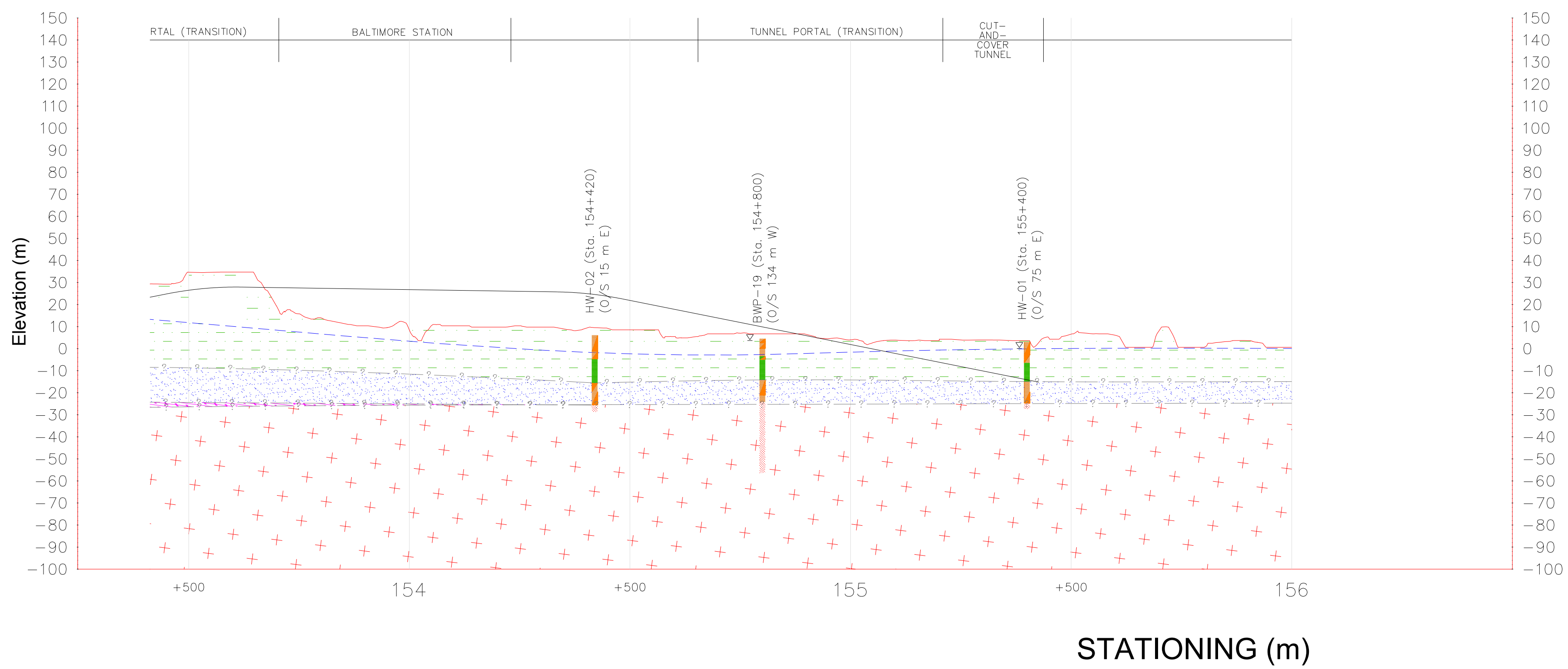

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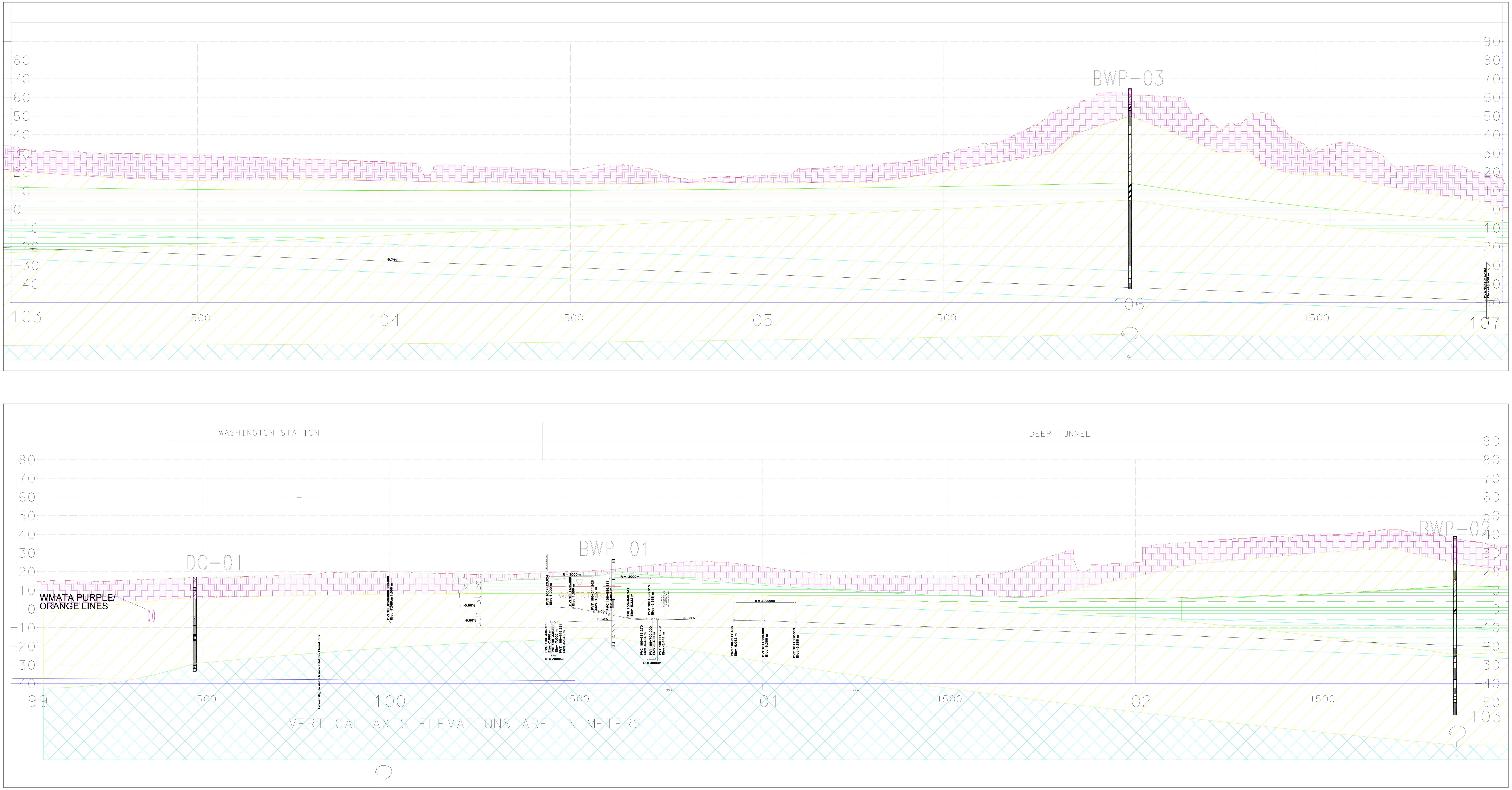
SCALE:	CONTR. No.	FILE NAME: 0661 BWMLV	ISSUE	DRAWING No.: GP-24 REV 0 DATE: 12/04/2018 SHEET No. 12 OF 12

APPENDIX D: GENERALIZED GEOTECHNICAL PROFILES WITH RESPECT TO ALIGNMENTS

GEOTECHNICAL PROFILE WITH RESPECT TO ALIGNMENT J1 OPTION 5

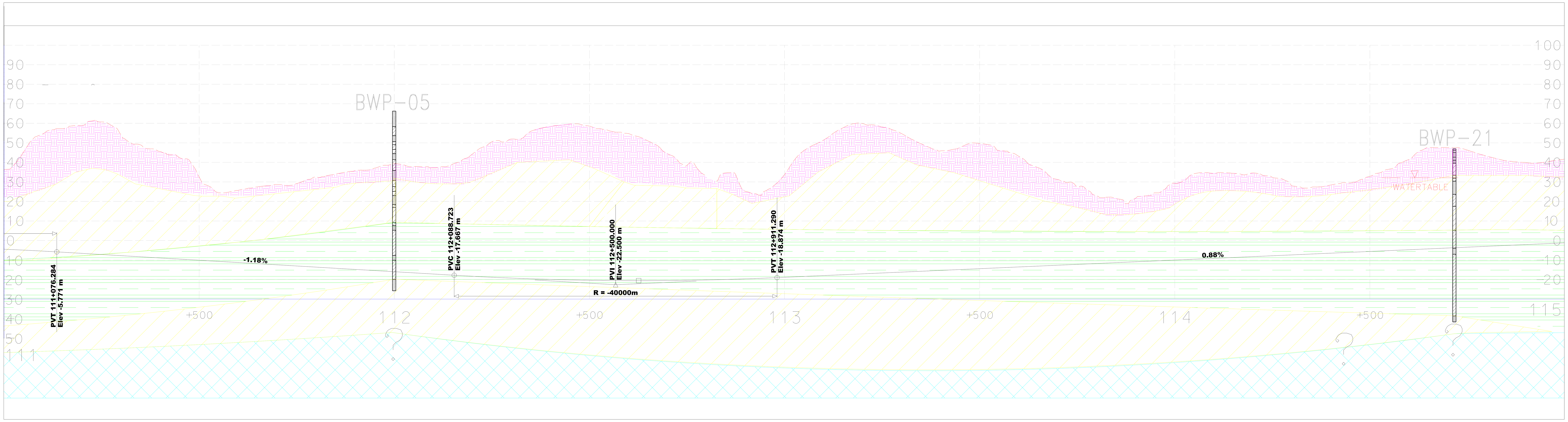


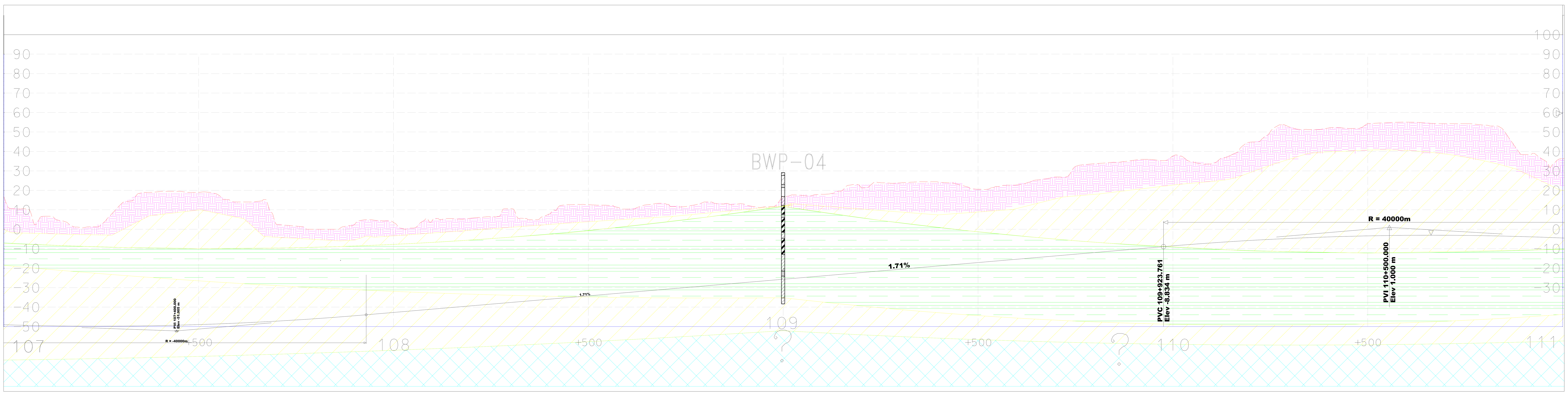
LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1A





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV	BWRR BALTIMORE-WASHINGTON RAPID RAIL / TNEM THE NORTHEAST MAGLEV	Generalized preliminary subsurface stratification based on 22 boreholes / Louis Berger	FIGURE 1B

LEGEND

FILL/UNCONSALIDATED SEDIMENTS

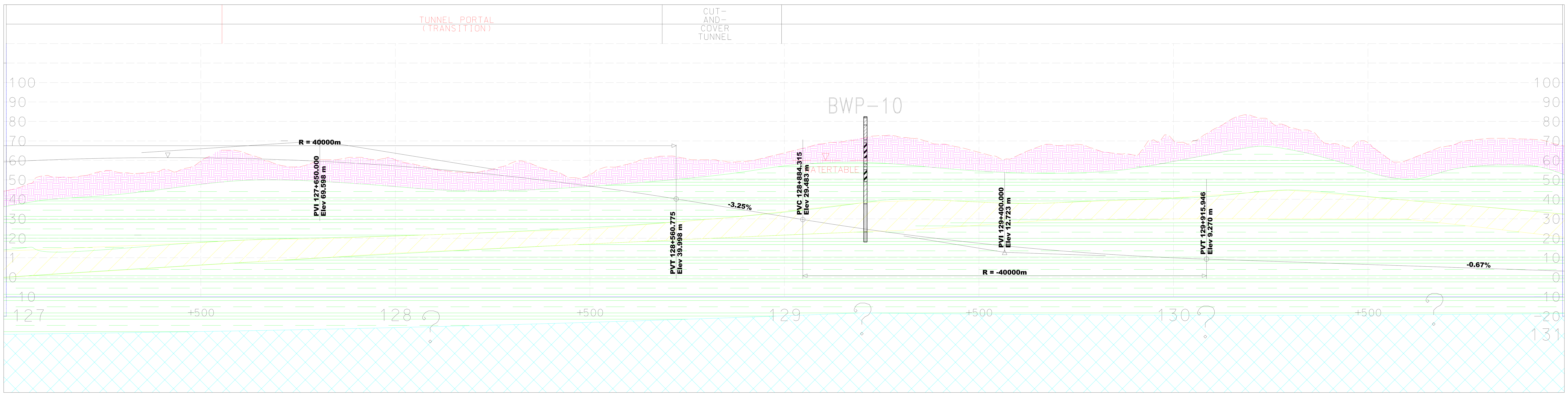
MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER

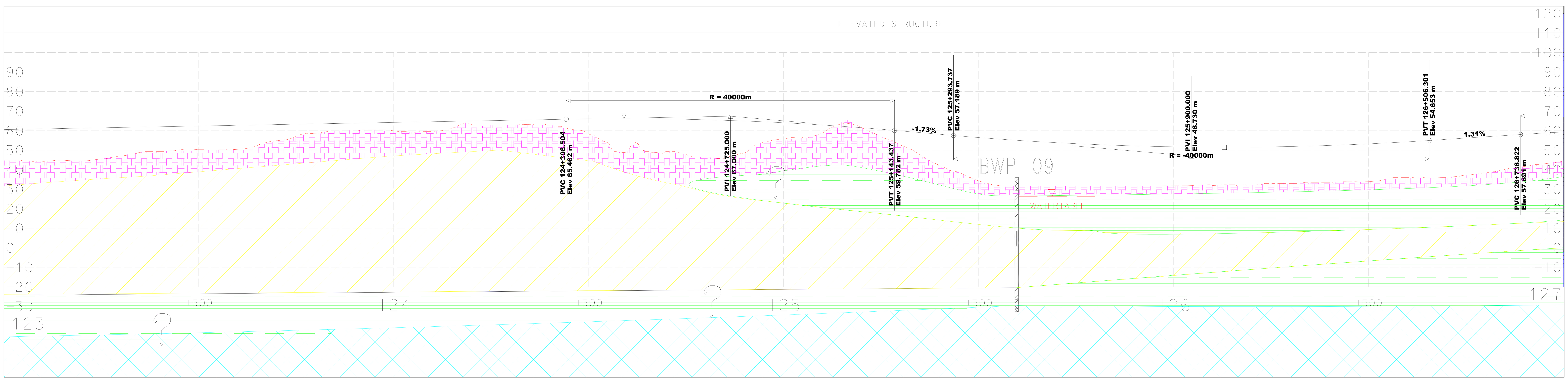
MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER

BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV	BWRR BALTIMORE-WASHINGTON RAPID RAIL	TNEM THE NORTHEAST MAGLEV	Generalized preliminary subsurface stratification based on 22 boreholes	Louis Berger	FIGURE 1C





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

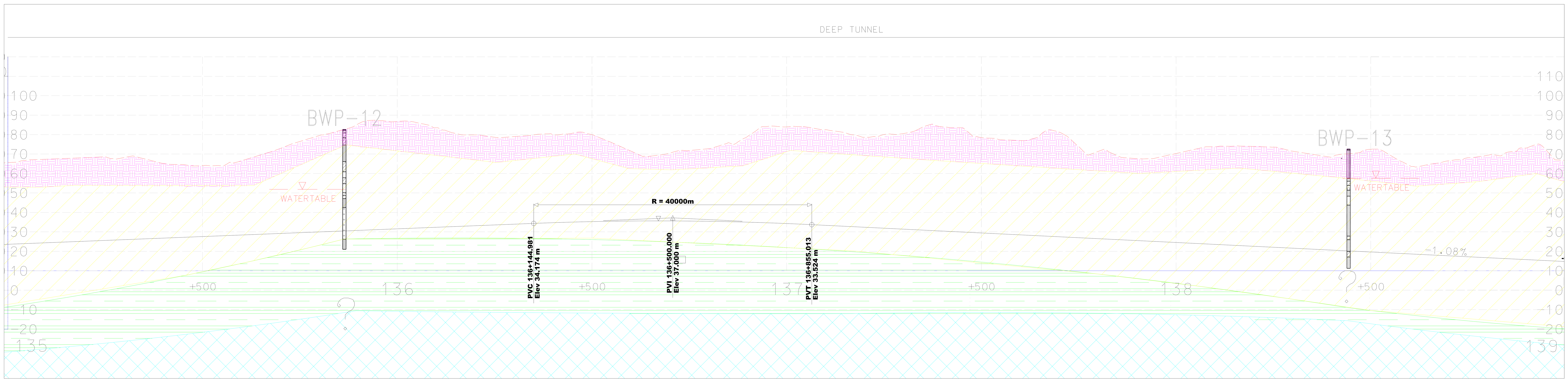
BWRR BALTIMORE-WASHINGTON RAPID RAIL

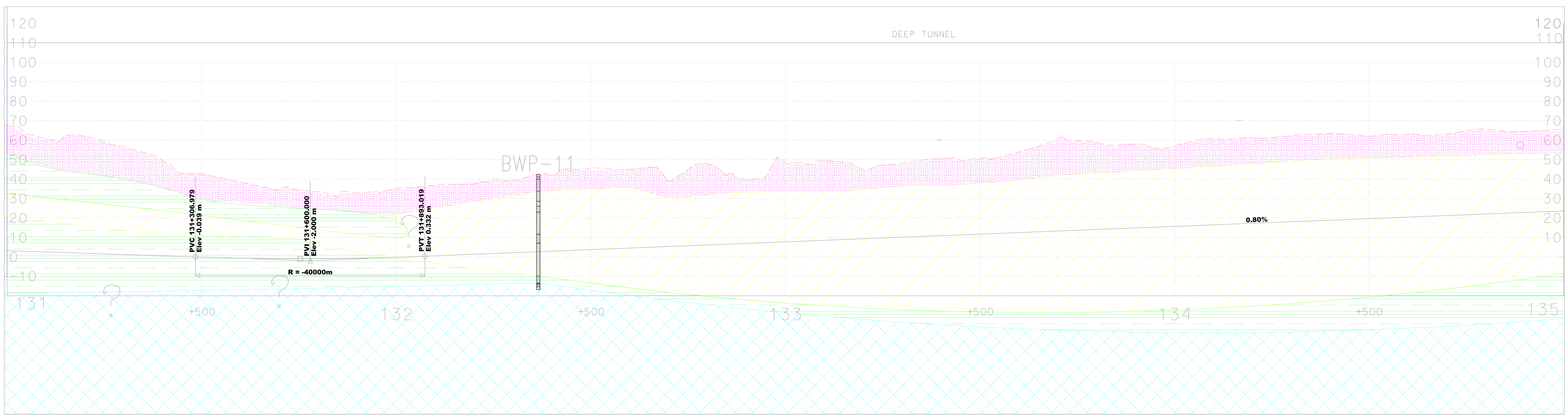
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1D





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

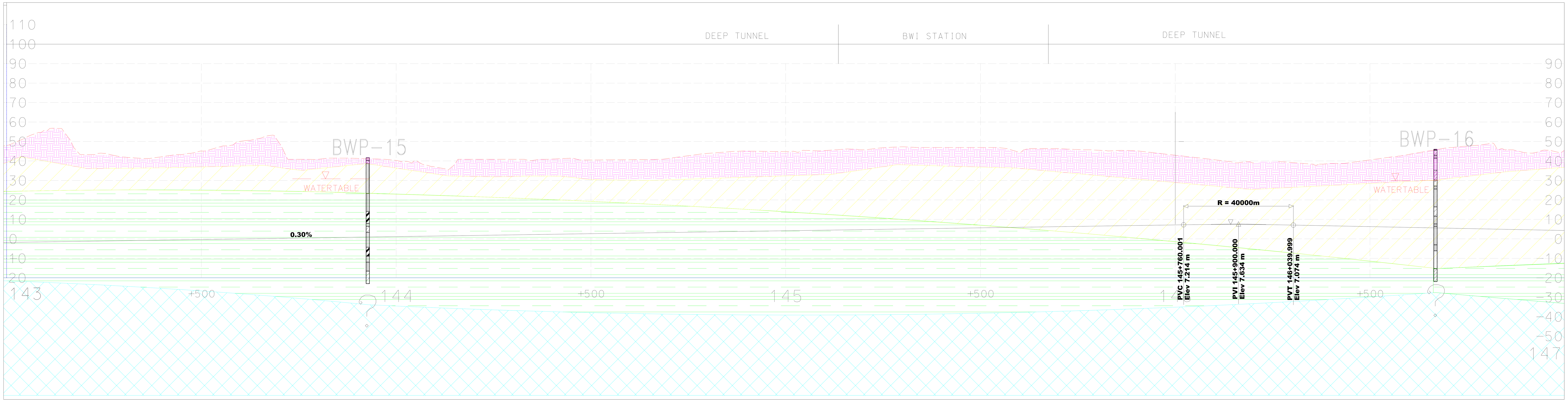
BWRR BALTIMORE-WASHINGTON RAPID RAIL

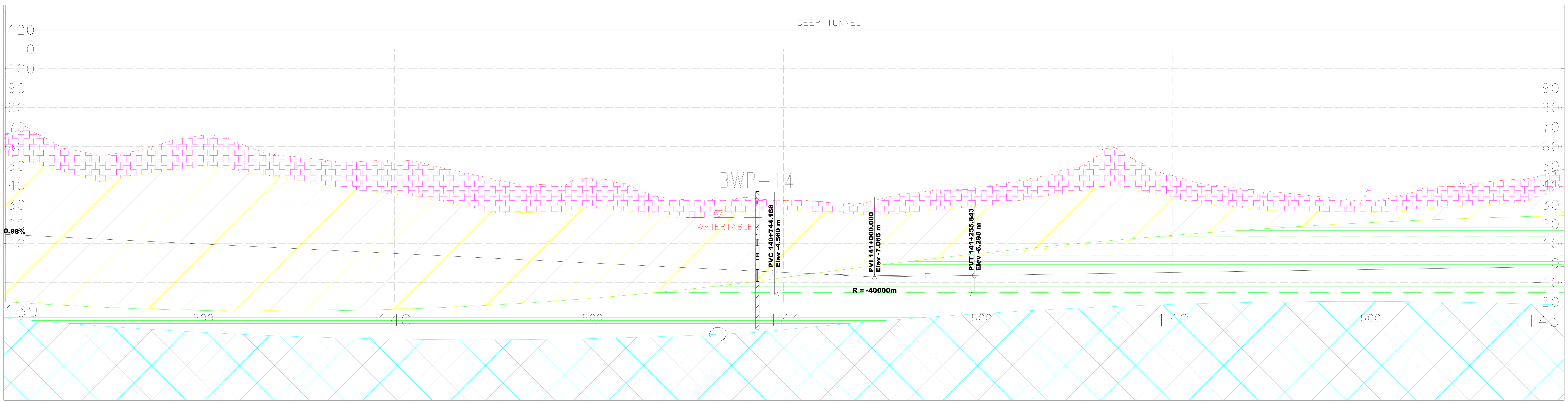
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1E





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1F

LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

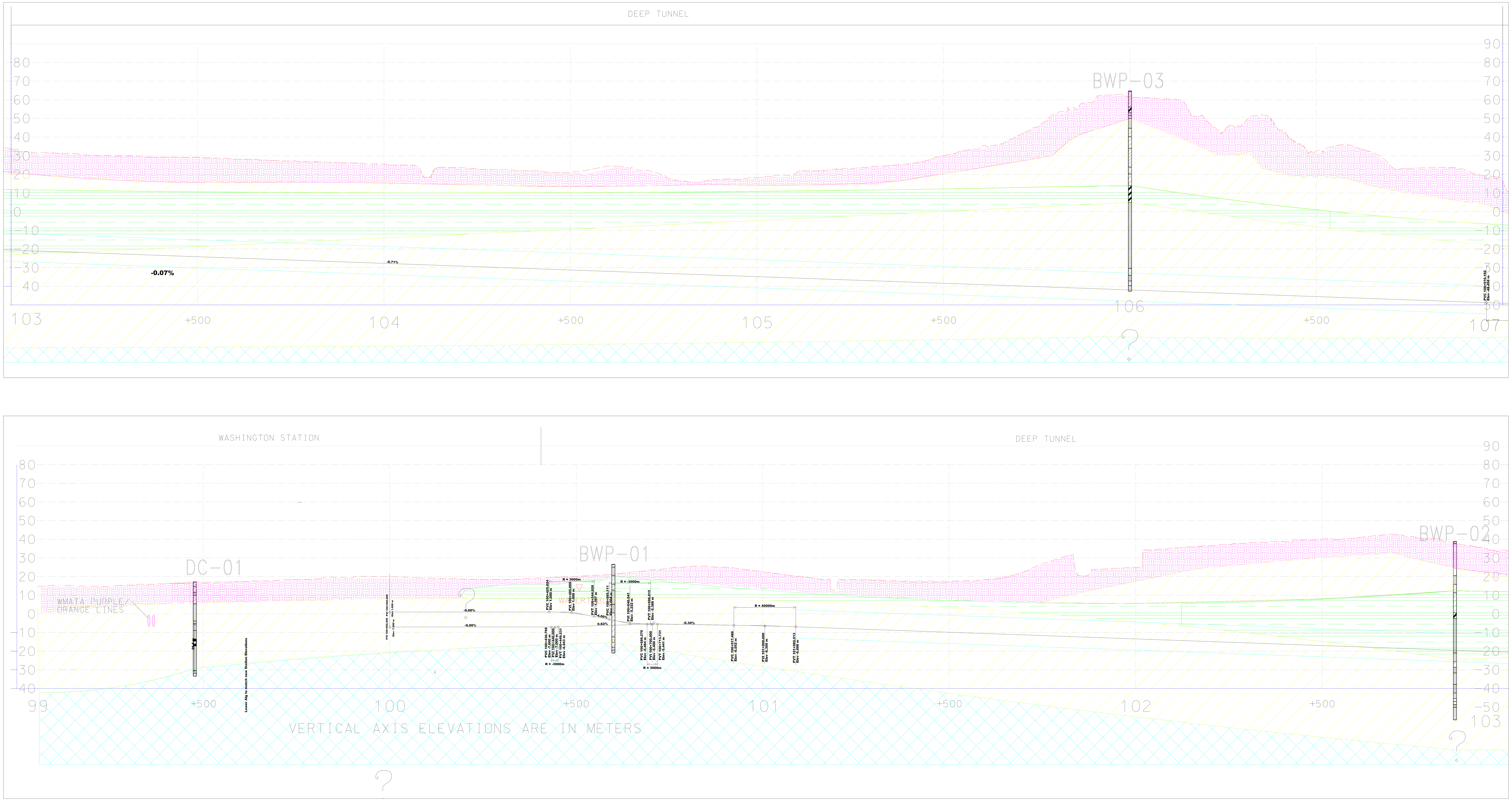
US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1G

GEOTECHNICAL PROFILE WITH RESPECT TO ALIGNMENT J MODIFIED 1



LEGEND

FILL/UNCONSALIDATED SEDIMENTS

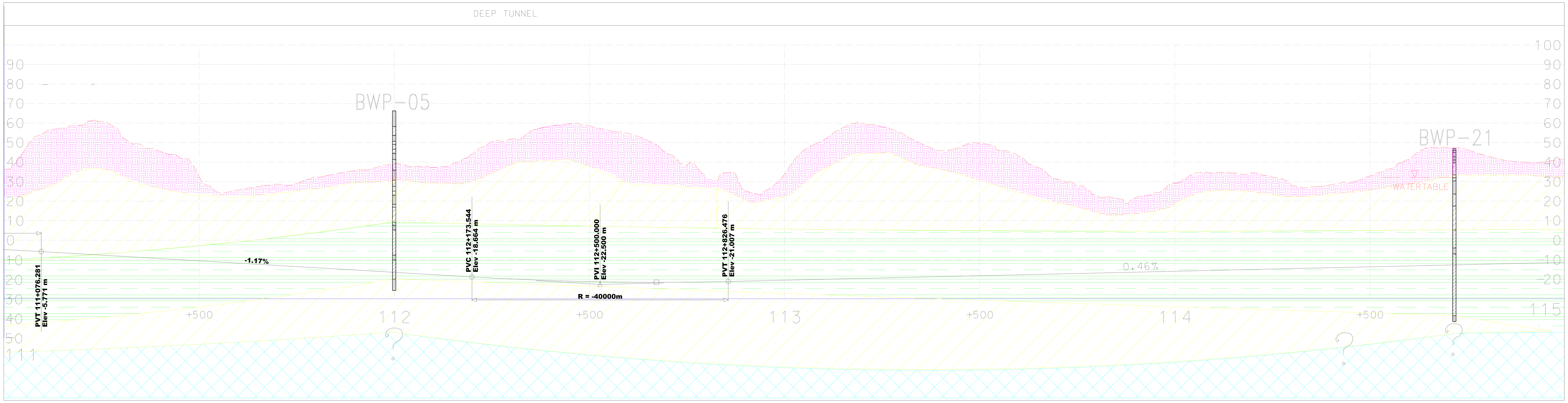
MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER

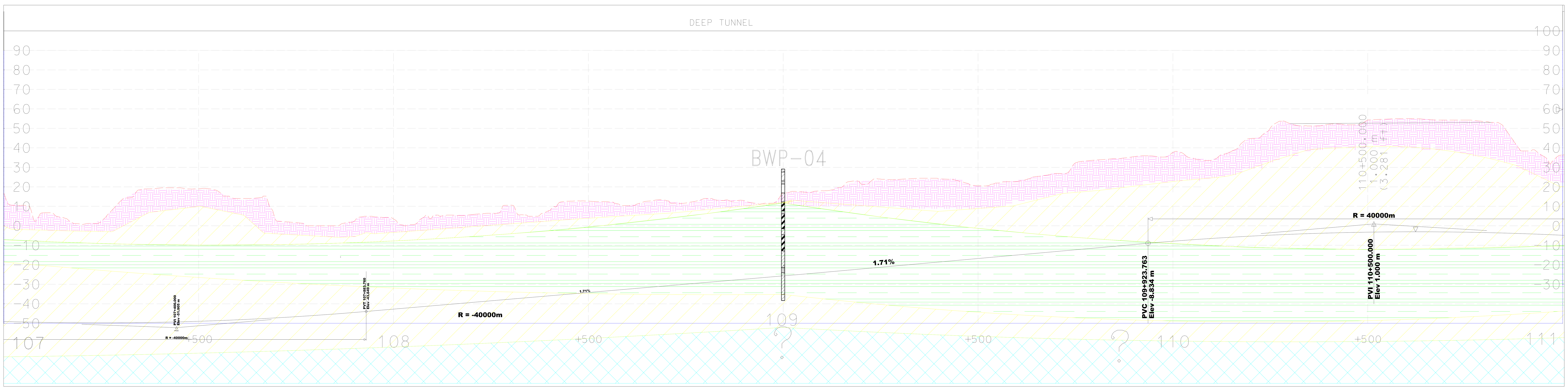
MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER

BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1A





LEGEND

FILL/UNCONSALIDATED SEDIMENTS

MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER

MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER

BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

BWRR BALTIMORE-WASHINGTON RAPID RAIL

TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

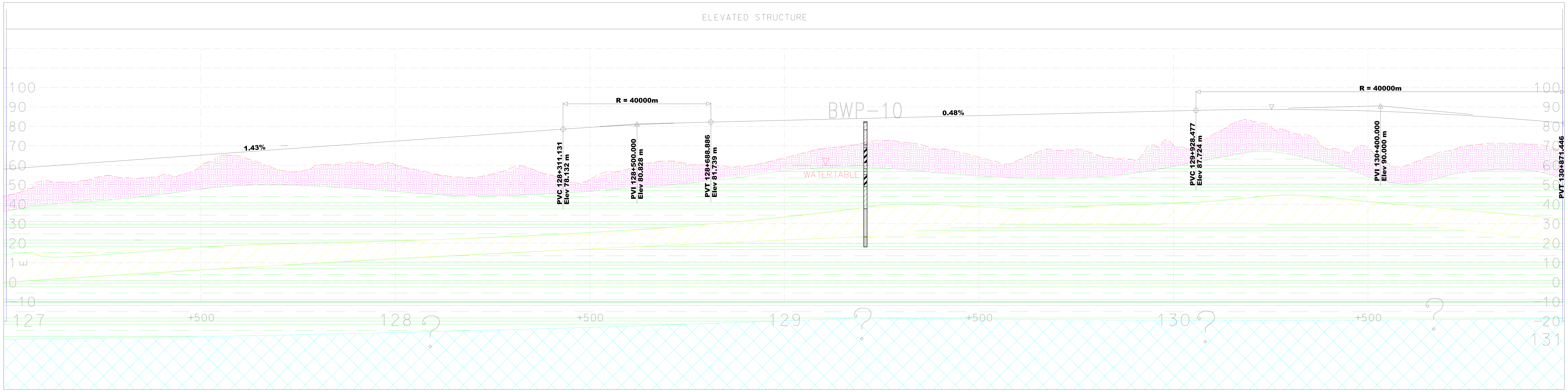
FIGURE 1B

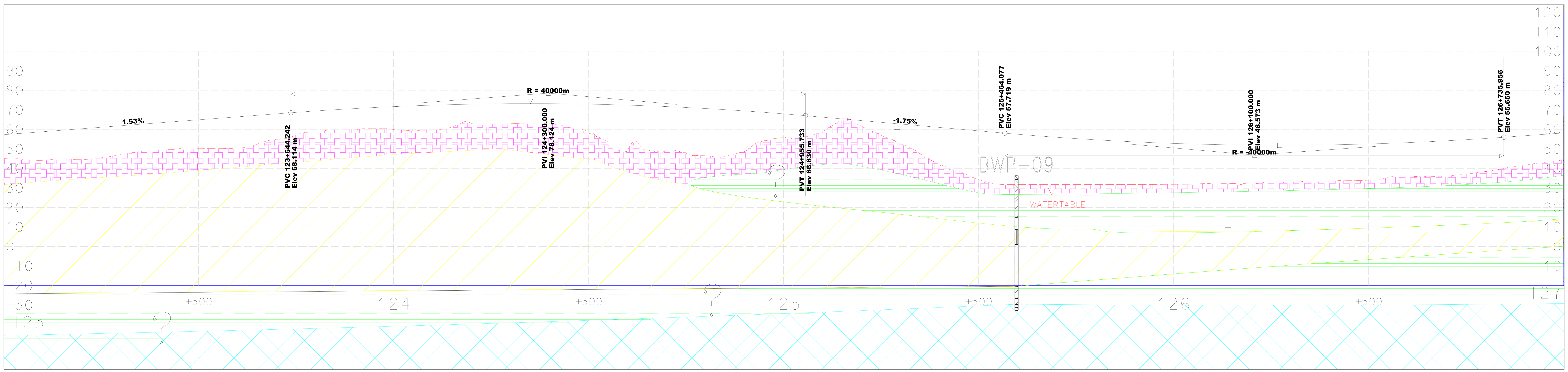
LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV | BWRR BALTIMORE-WASHINGTON RAPID RAIL | TNEM THE NORTHEAST MAGLEV | Generalized preliminary subsurface stratification based on 22 boreholes | Louis Berger | FIGURE 1C





LEGEND

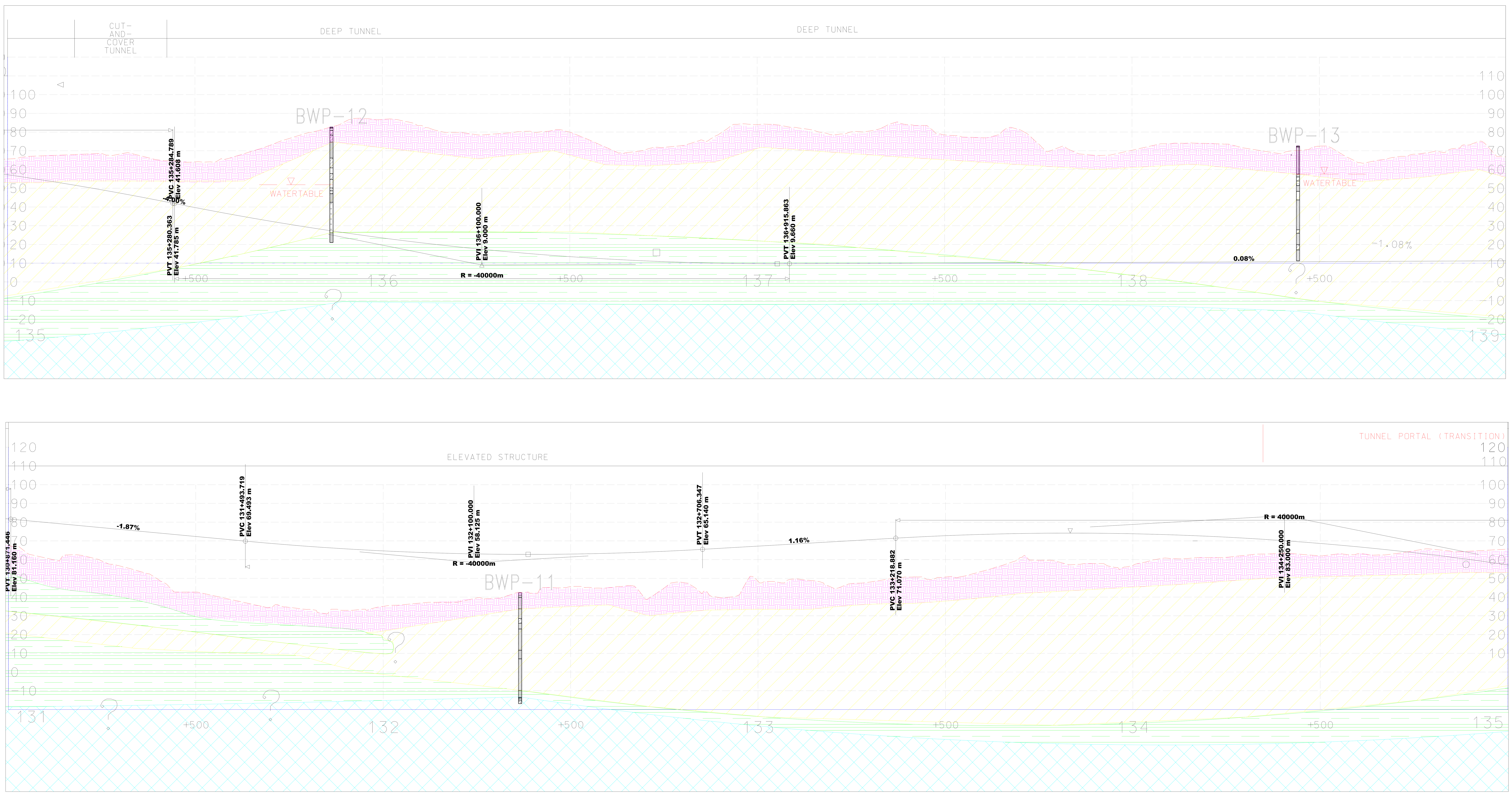
- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

FIGURE 1D



LEGEND

FILL/UNCONSALIDATED SEDIMENTS	MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER	BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

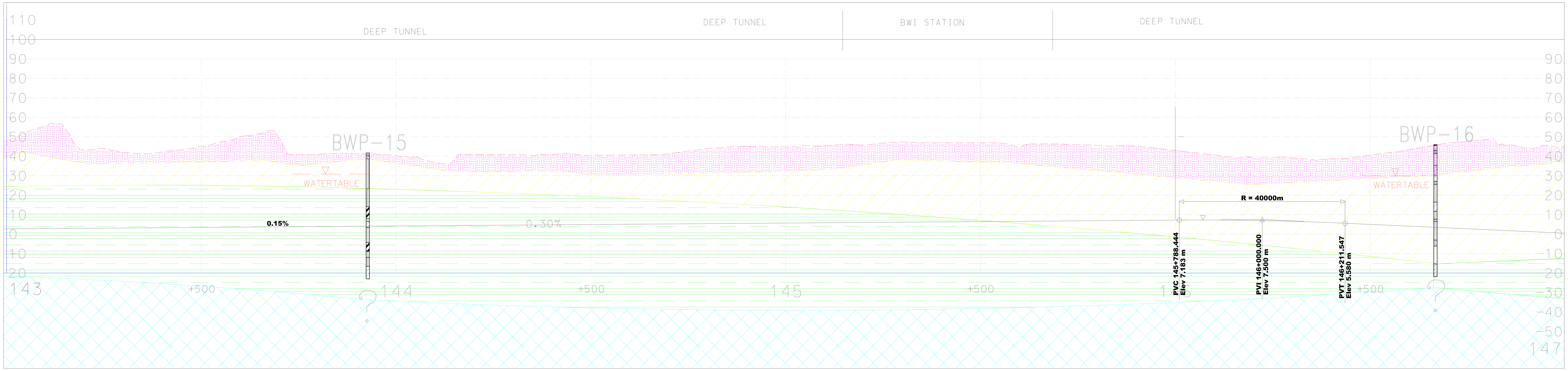
BWRR BALTIMORE-WASHINGTON RAPID RAIL

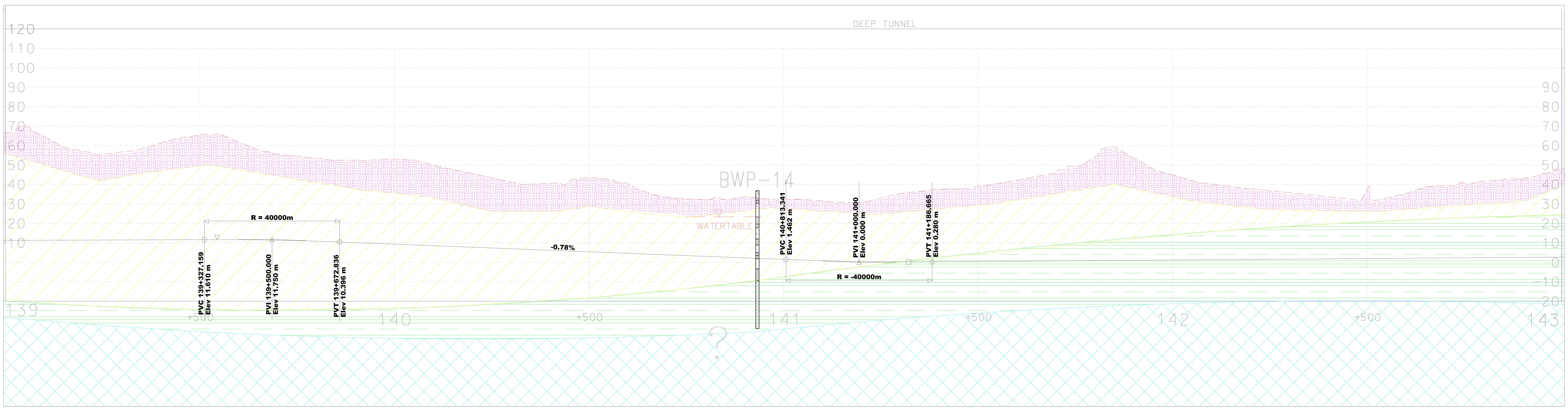
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1E





LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

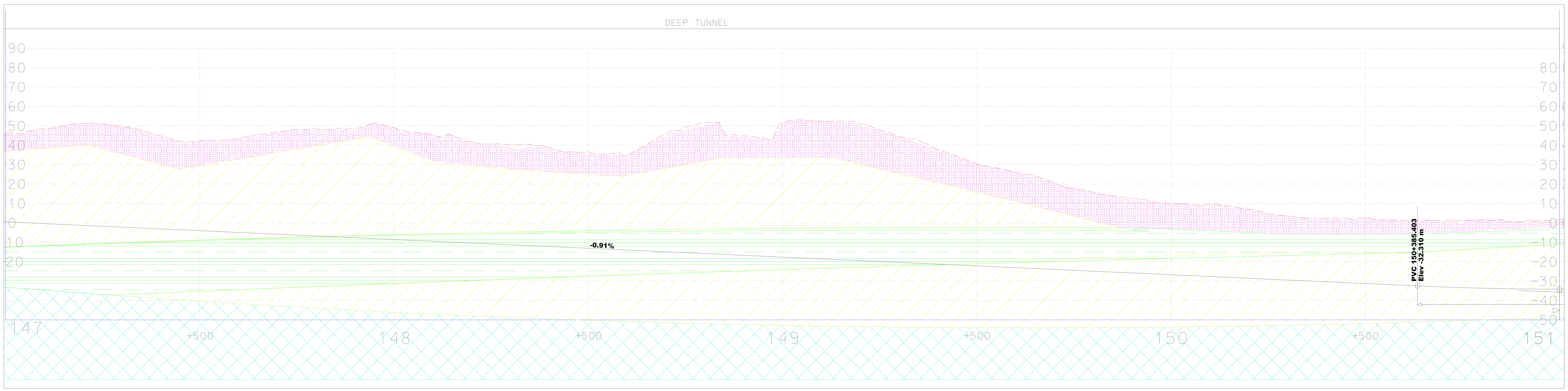
BWRR BALTIMORE-WASHINGTON RAPID RAIL

TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

Louis Berger

FIGURE 1F



LEGEND

- FILL/UNCONSALIDATED SEDIMENTS
- MOSTLY VERY STIFF/HARD CLAY/SILT WITH VERY DENSE SAND LAYER
- MOSTLY VERY DENSE SAND WITH VERY STIFF/HARD CLAY/SILT LAYER
- BEDROCK GNESIS

PLEASE REFER TO THE GEOTECHNICAL REPORT FOR THE DESCRIPTION OF THE STRATA

US MAGLEV

BWRR BALTIMORE-WASHINGTON RAPID RAIL

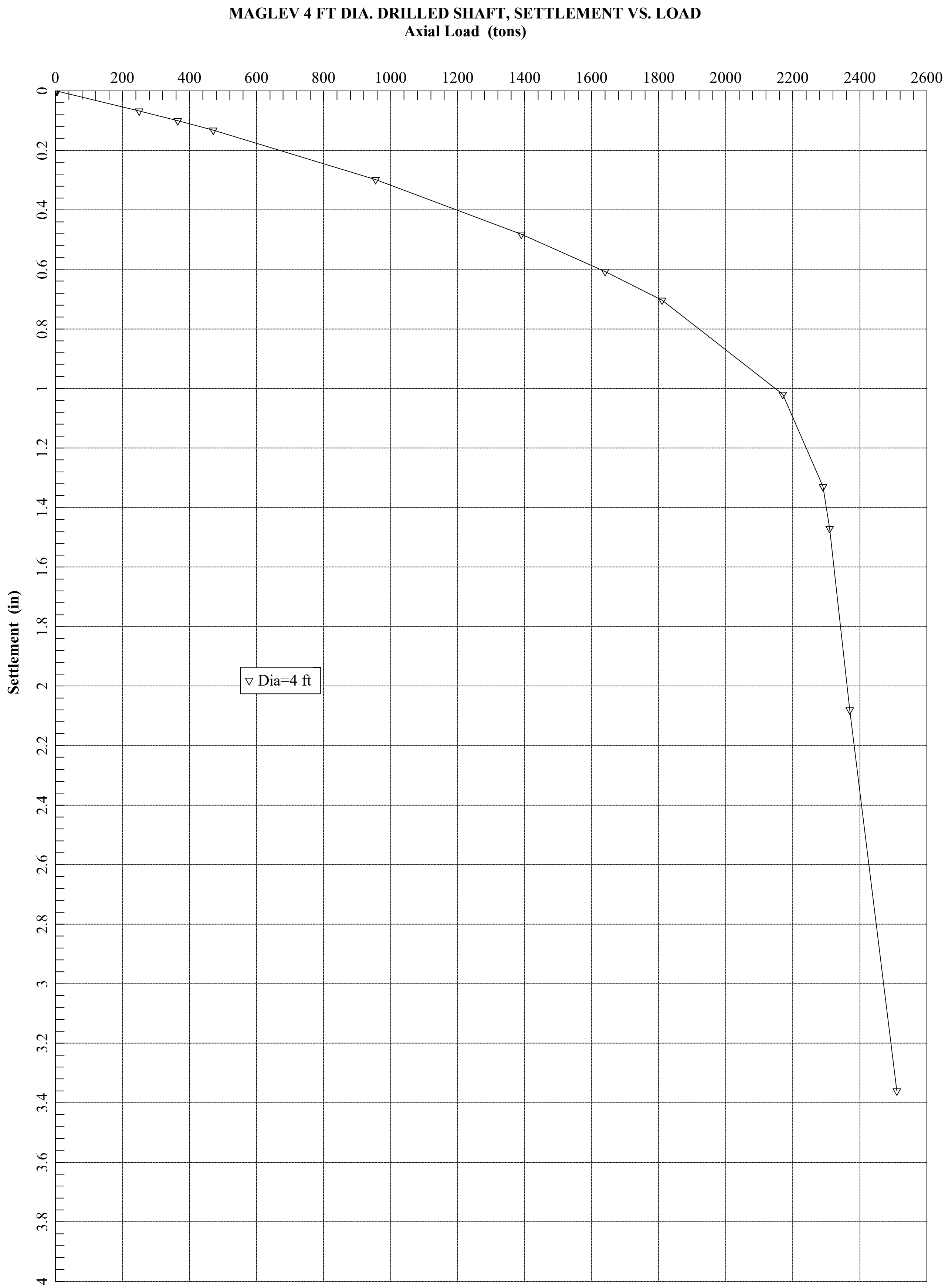
TNEM THE NORTHEAST MAGLEV

Generalized preliminary subsurface stratification based on 22 boreholes

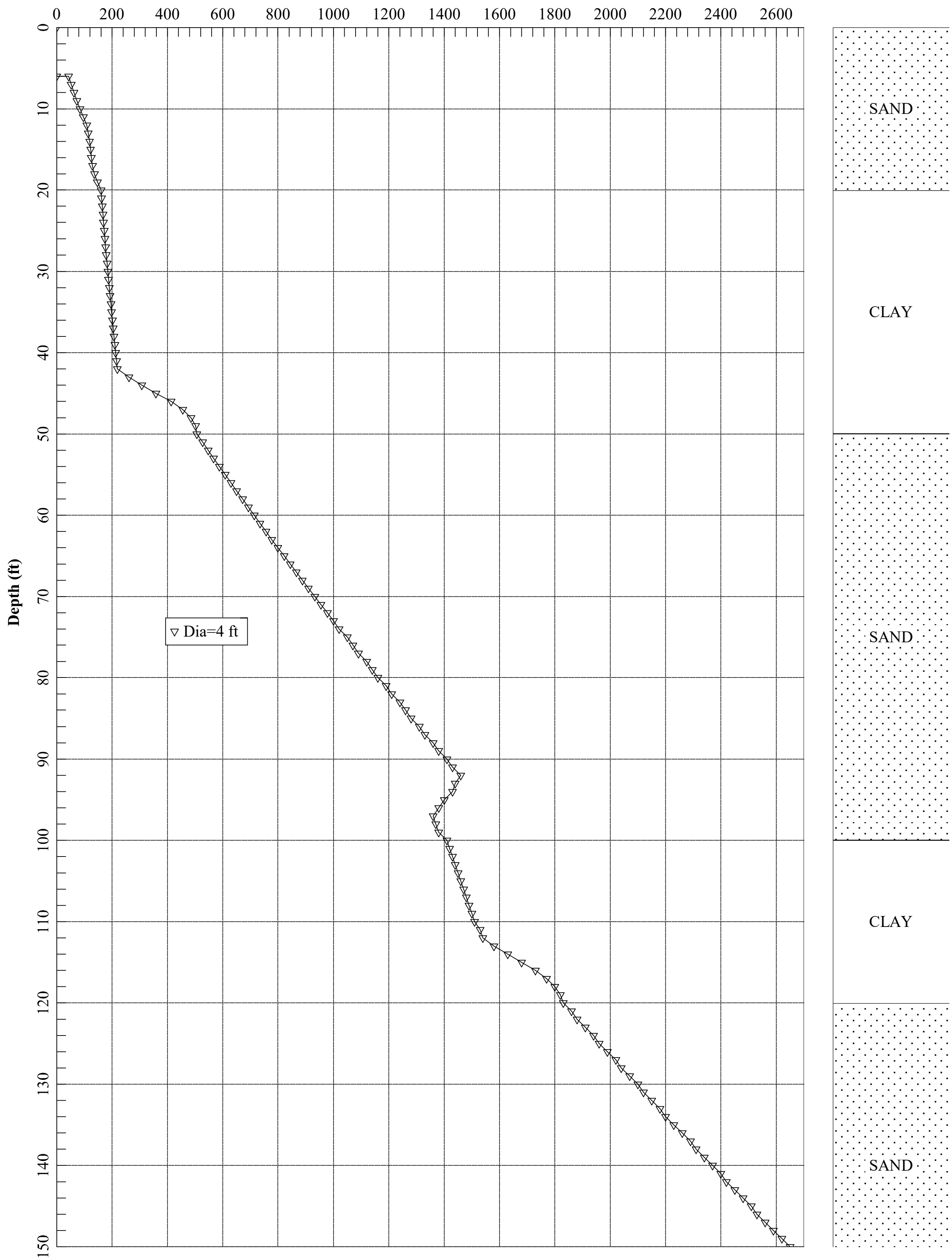
Louis Berger

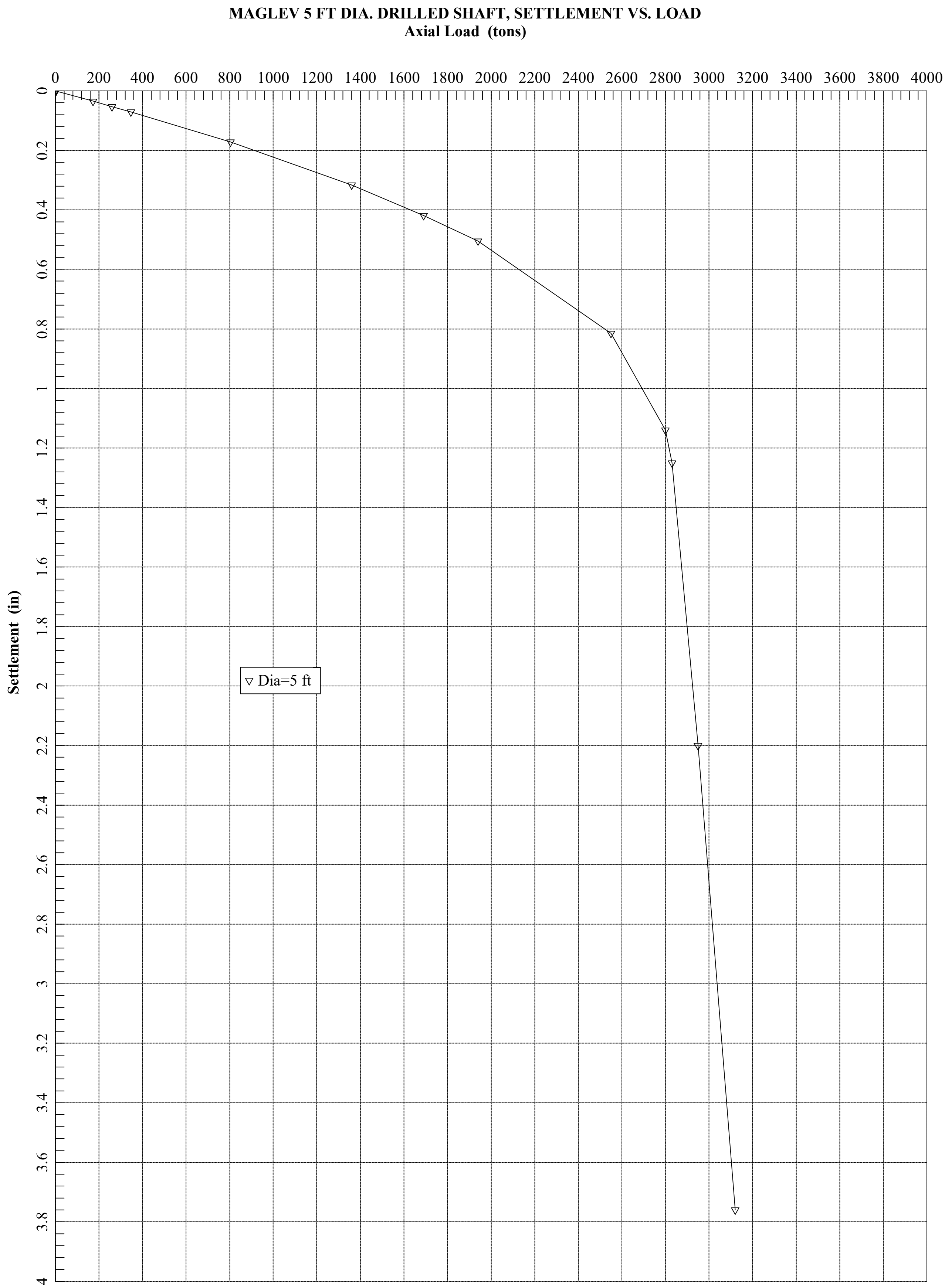
FIGURE 1G

APPENDIX E: DRILLED SHAFT CAPACITY ANALYSIS


MAGLEV 4 FT DIA. DRILLED SHAFT, SETTLEMENT VS. LOAD
Axial Load (tons)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Settlement (in)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
Dia=4 ft

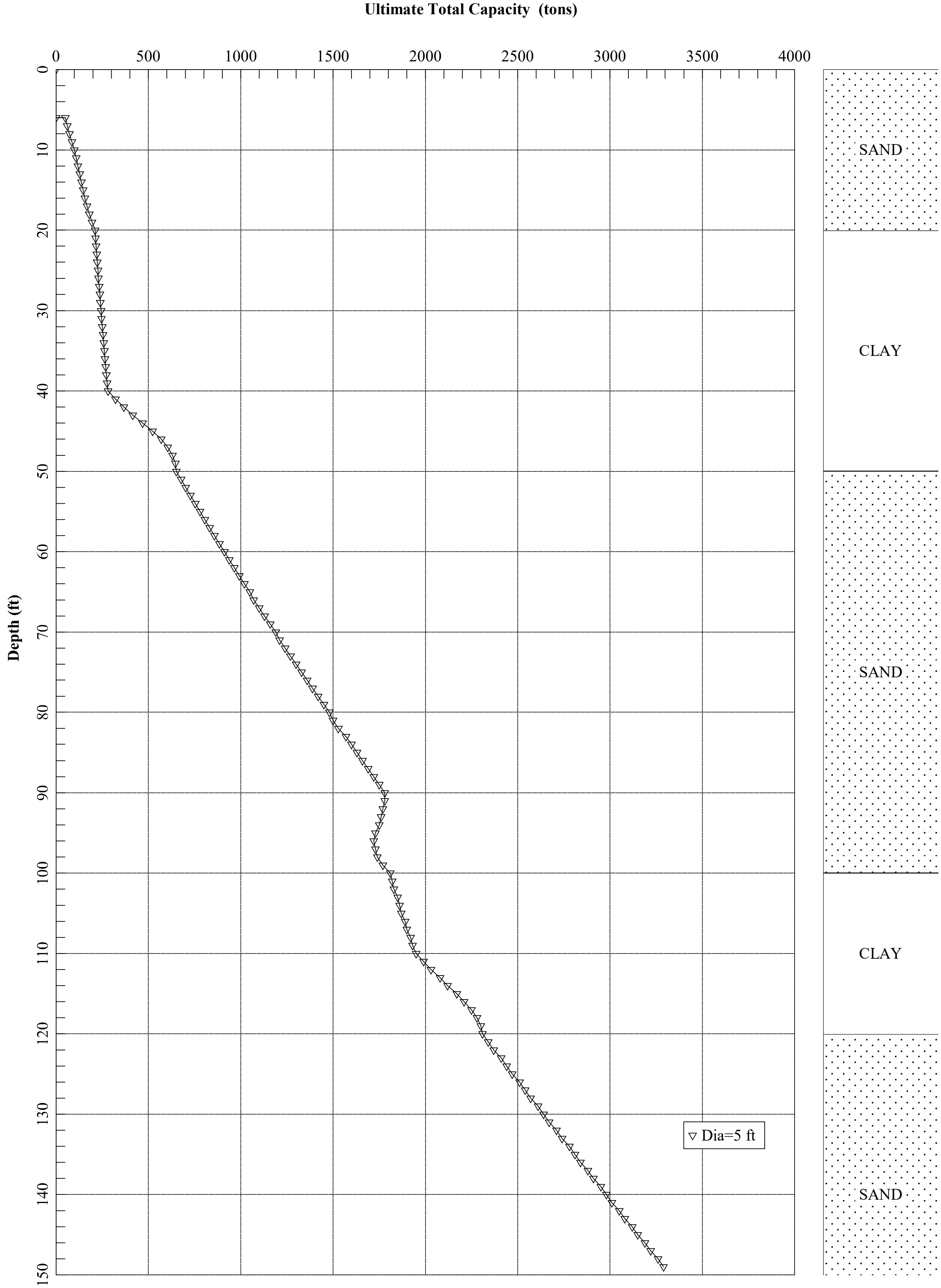
MAGLEV 4 FT DIA. DRILLED SHAFT, NOMINAL RESISTANCE IN COMPRESSION
Ultimate Total Capacity (tons)

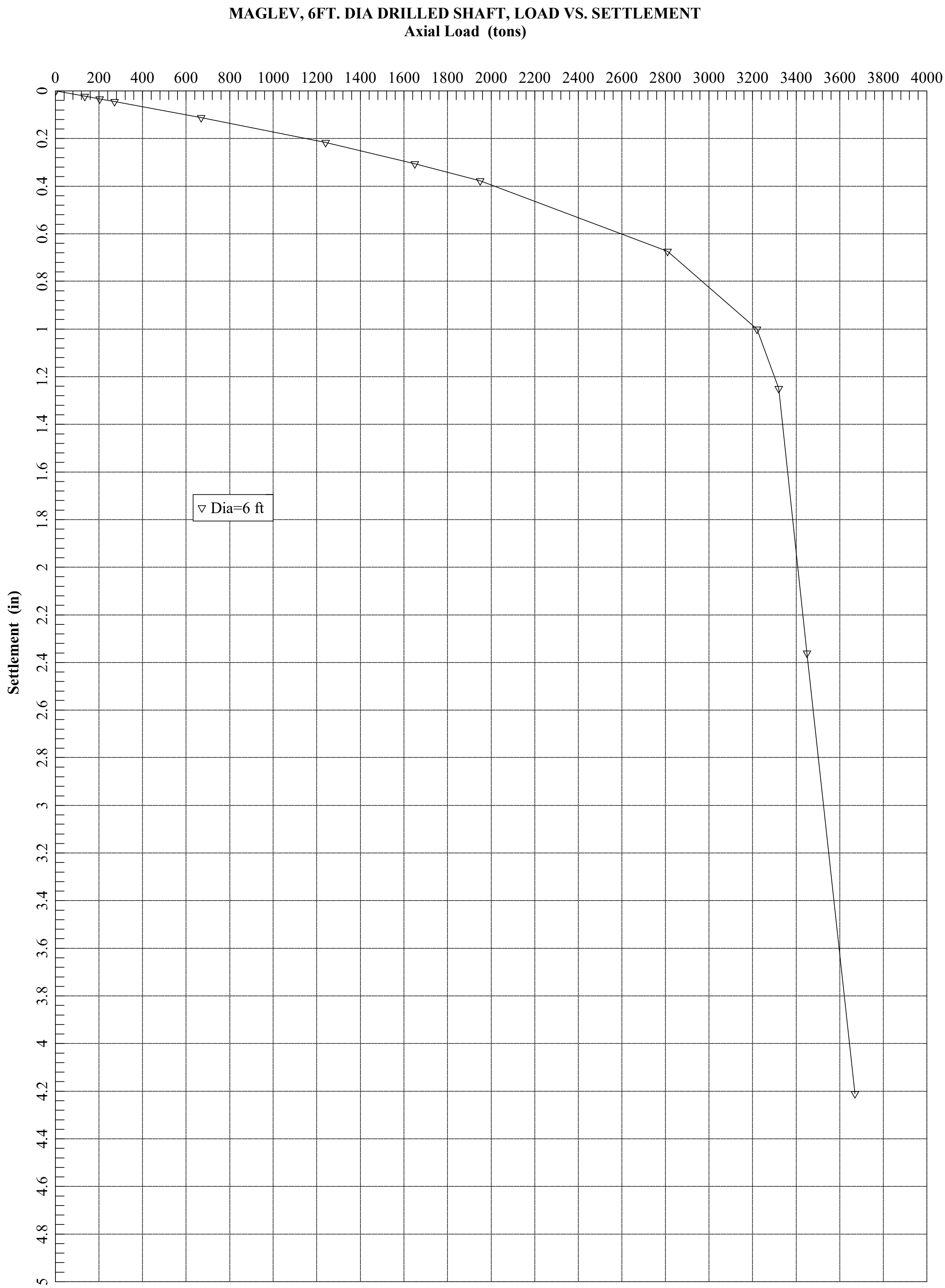




MAGLEV 5 FT DIA. DRILLED SHAFT, SETTLEMENT VS. LOAD
Axial Load (tons)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
Settlement (in)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4
Dia=5 ft

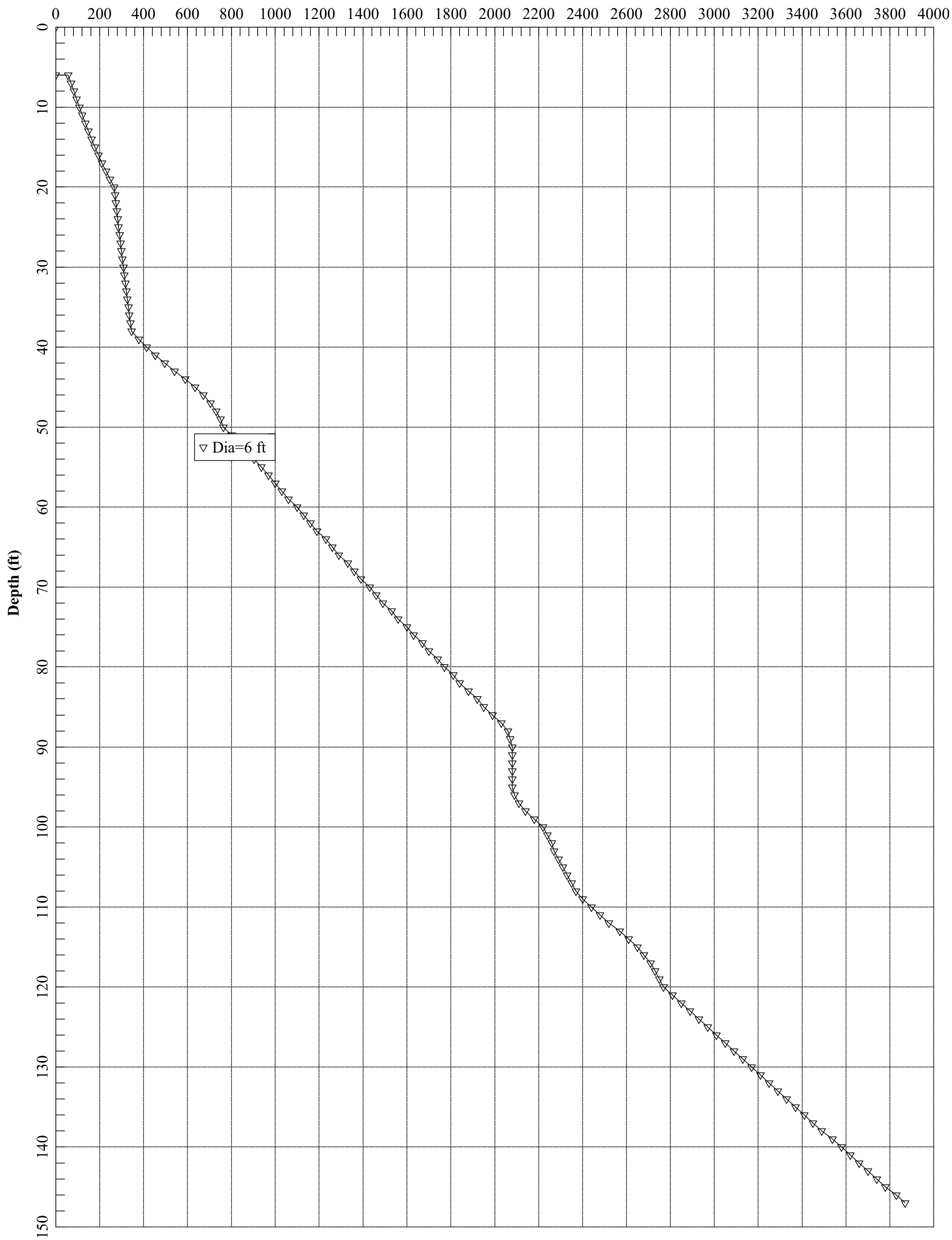
MAGLEV 5 FT DIA. DRILLED SHAFT, NOMINAL RESISTANCE IN COMPRESSION



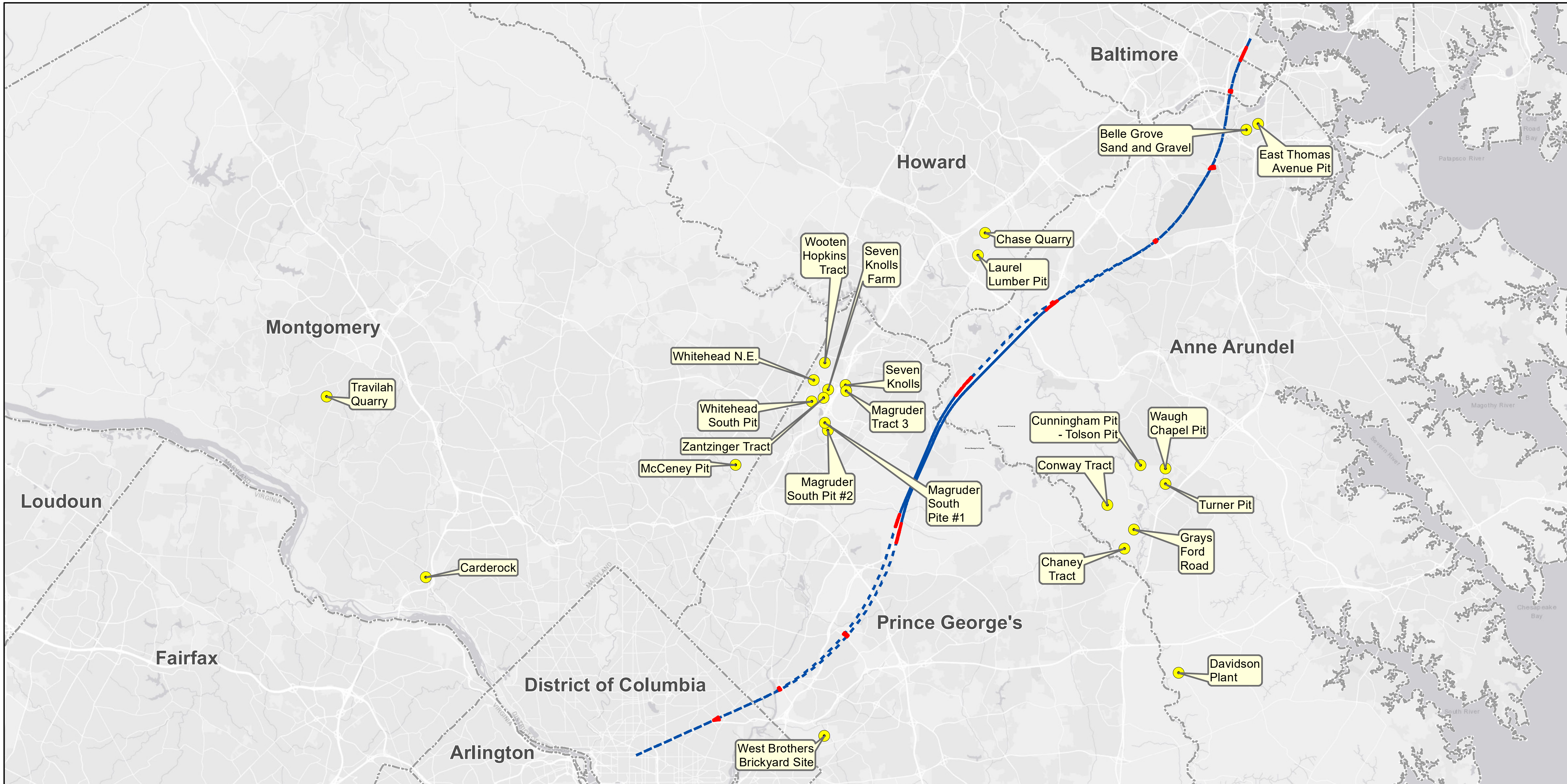


MAGLEV, 6FT. DIA DRILLED SHAFT, LOAD VS. SETTLEMENT
Axial Load (tons)
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000
Settlement (in)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5
Dia=6 ft

MAGLEV-6FT. DIA DRILLED SHAFT NOMINAL RESISTANCE Vs. DEPTH
LRFD Total Resistance (tons)



APPENDIX F: SOIL DISPOSAL ROUTES



Active Mining Locations
Laydown Area
Elevated Structure
Deep Tunnel
County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

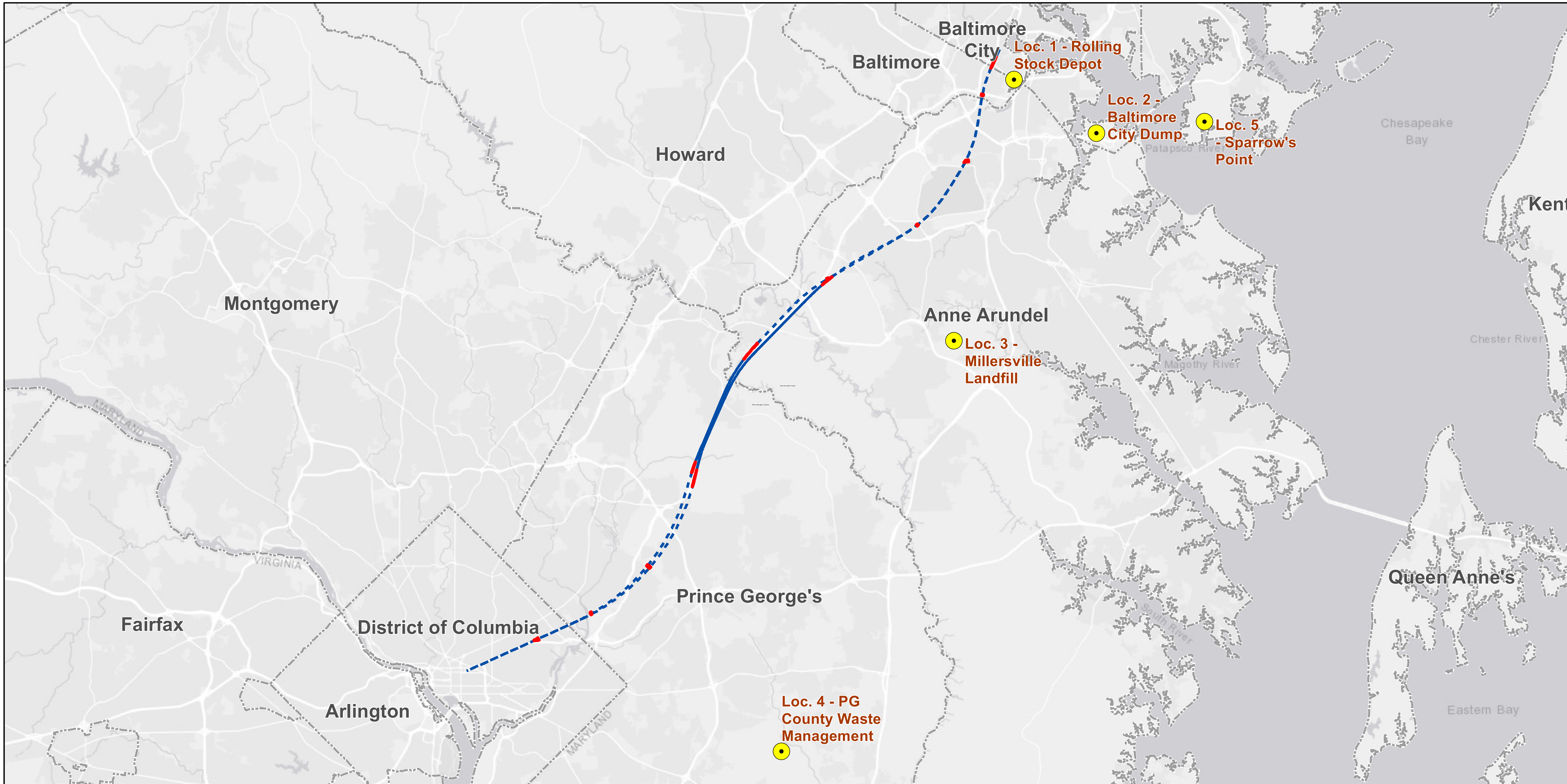
November 07, 2018

Potential Other Spoil Disposal Sites

BWRR Louis Berger

0 2 4 6 8 Miles

N

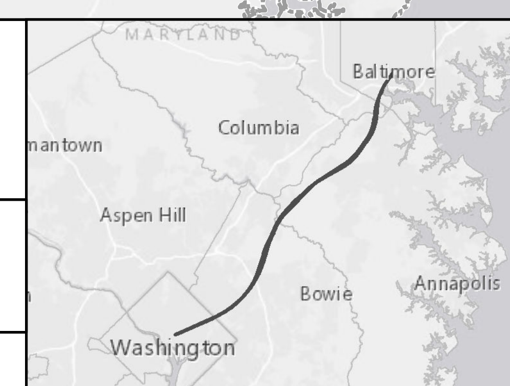


Potential Spoil Site
Laydown Area
Elevated Structure
Deep Tunnel
County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

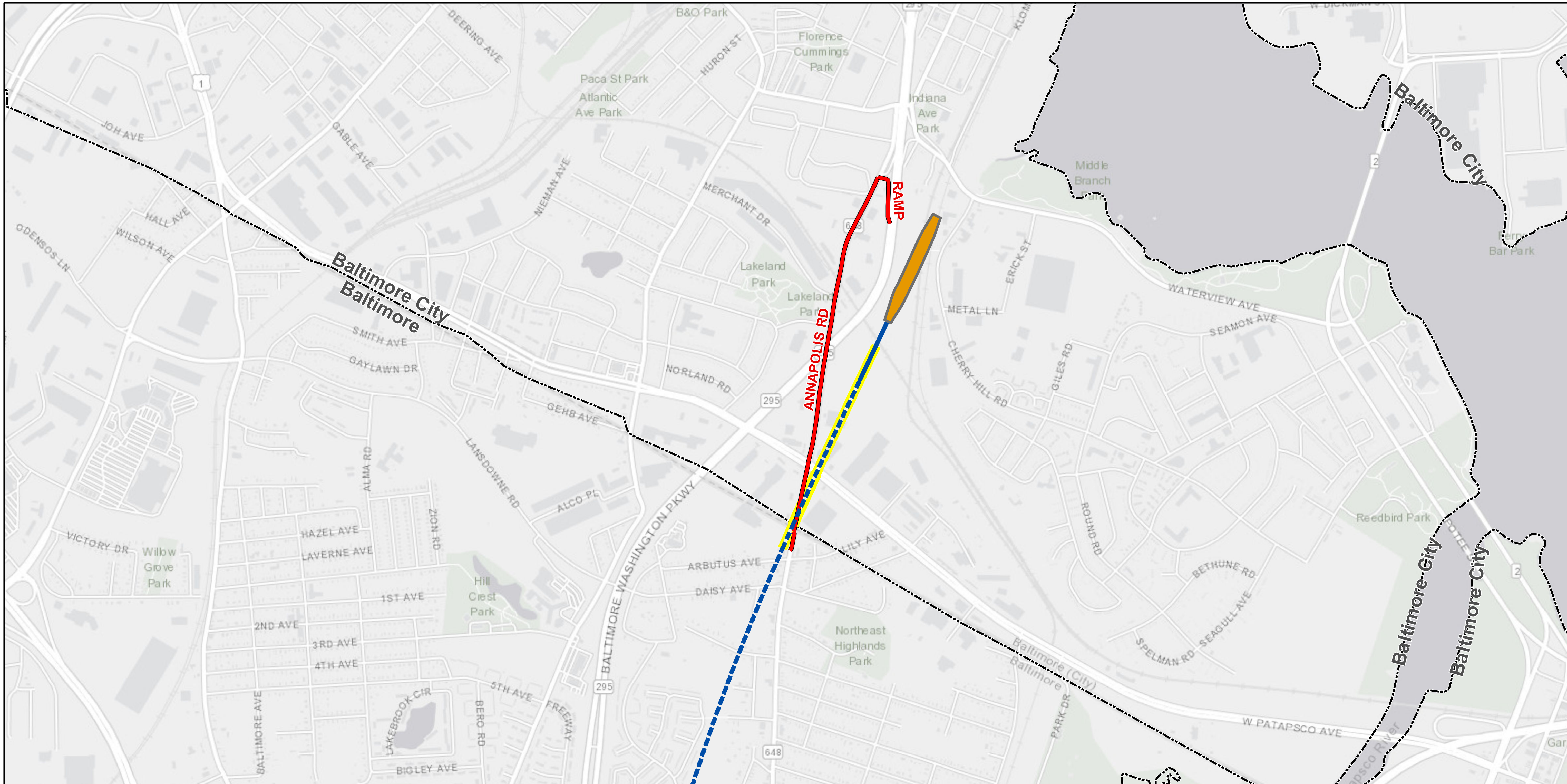


Proposed Spoil Destinations

BWRR
Louis Berger

0 2 4 6 8 Miles

N



Truck Route	Sources: ESRI (2017), BWRR (2017)	
Laydown Area	Coordinate System: NAD 1983 StatePlane MD (feet) Datum: North American 1983	
Elevated Structure	October 22, 2018	
Deep Tunnel		
County Boundary		

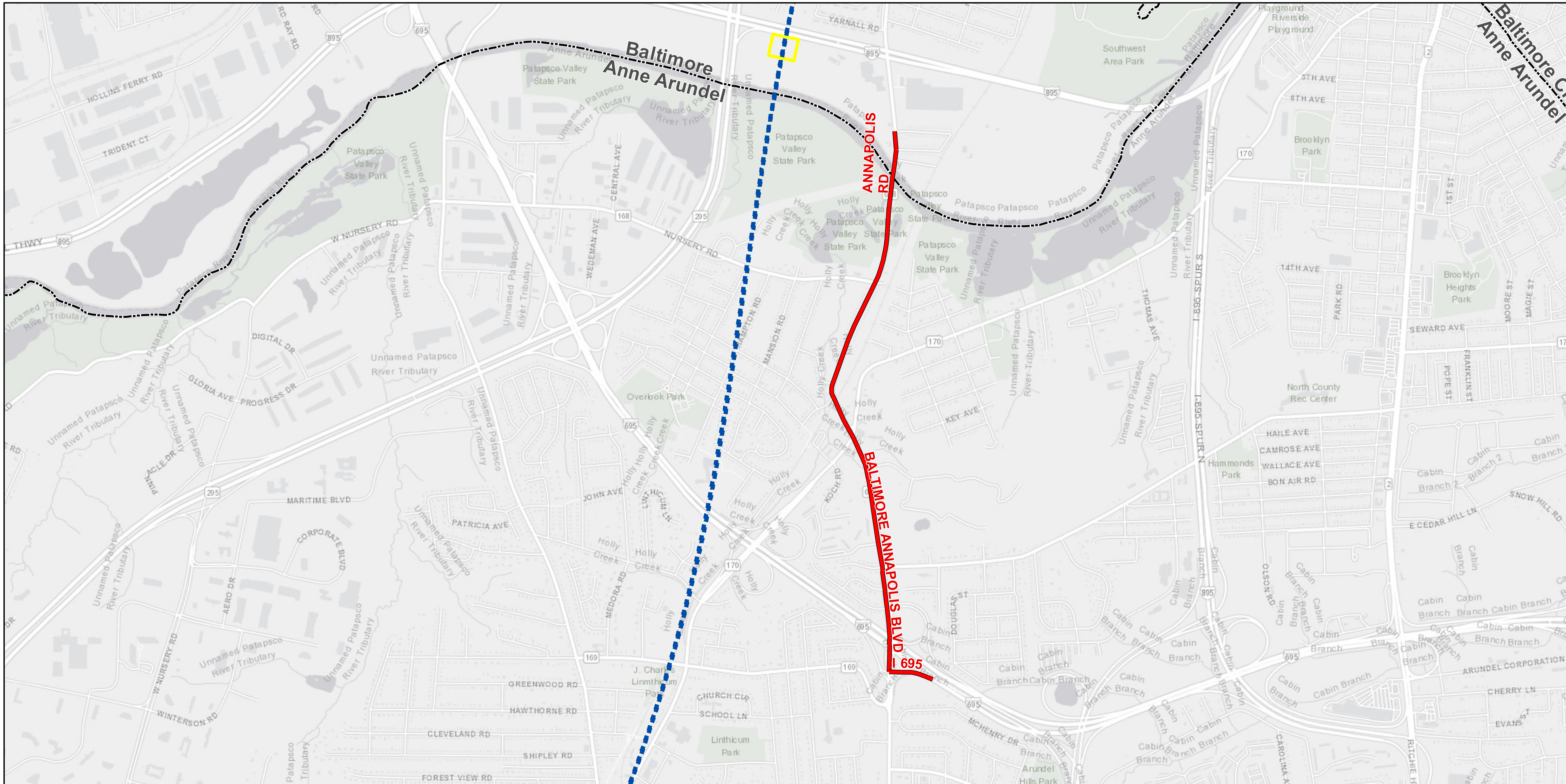
Cherry Hill Portal
Proposed Haul Route

BWRR
BALTIMORE-WASHINGTON RAPID RAIL

Louis Berger

0 0.25 0.5 Miles

N

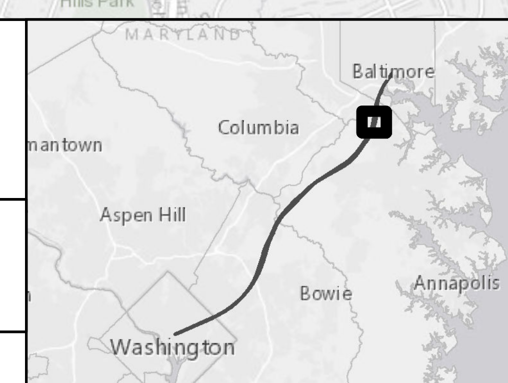


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

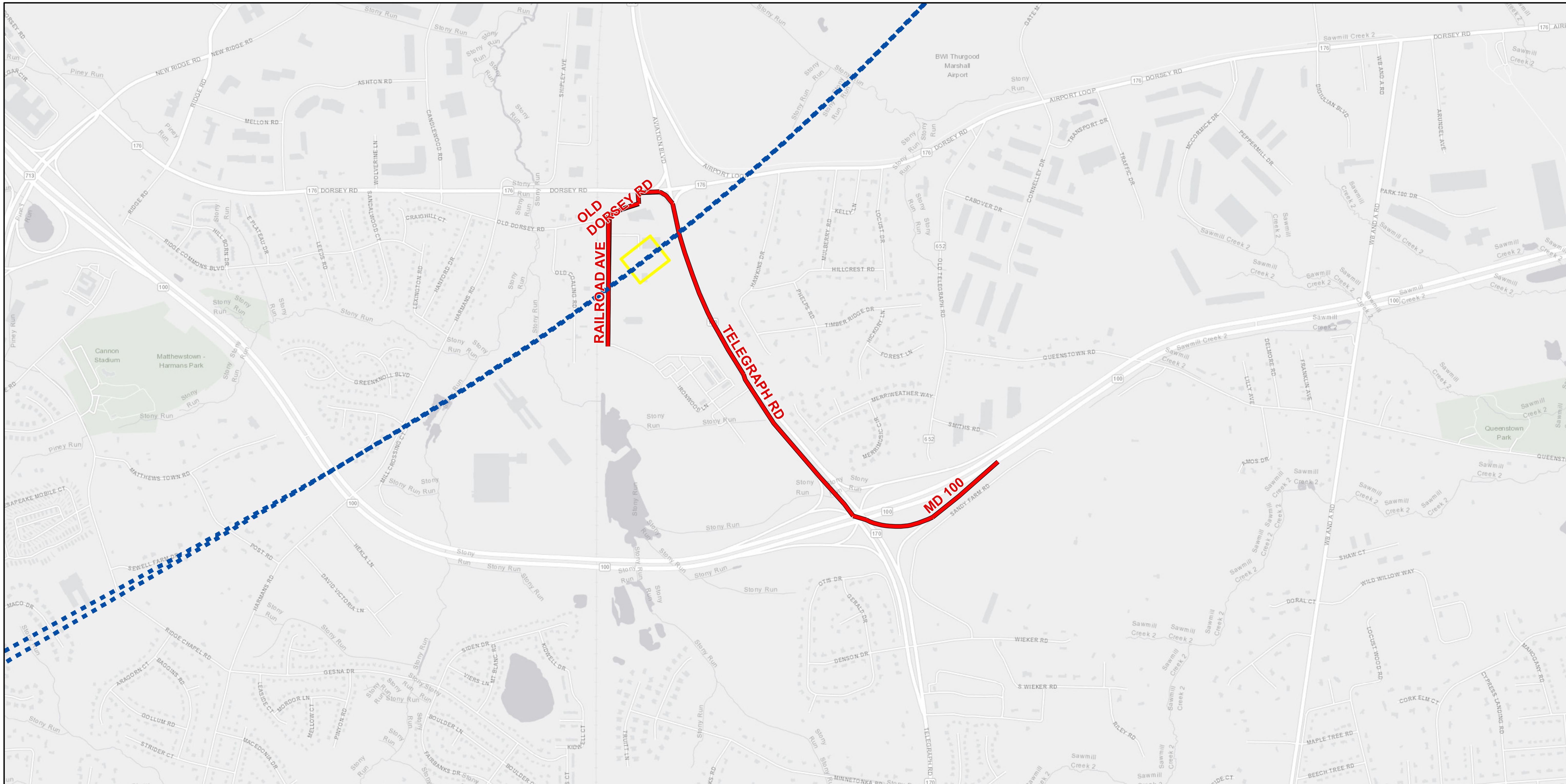


I-895 Vent Plant
Proposed Haul Route

BWRR
Louis Berger

0 0.25 0.5 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet) Datum: North American 1983

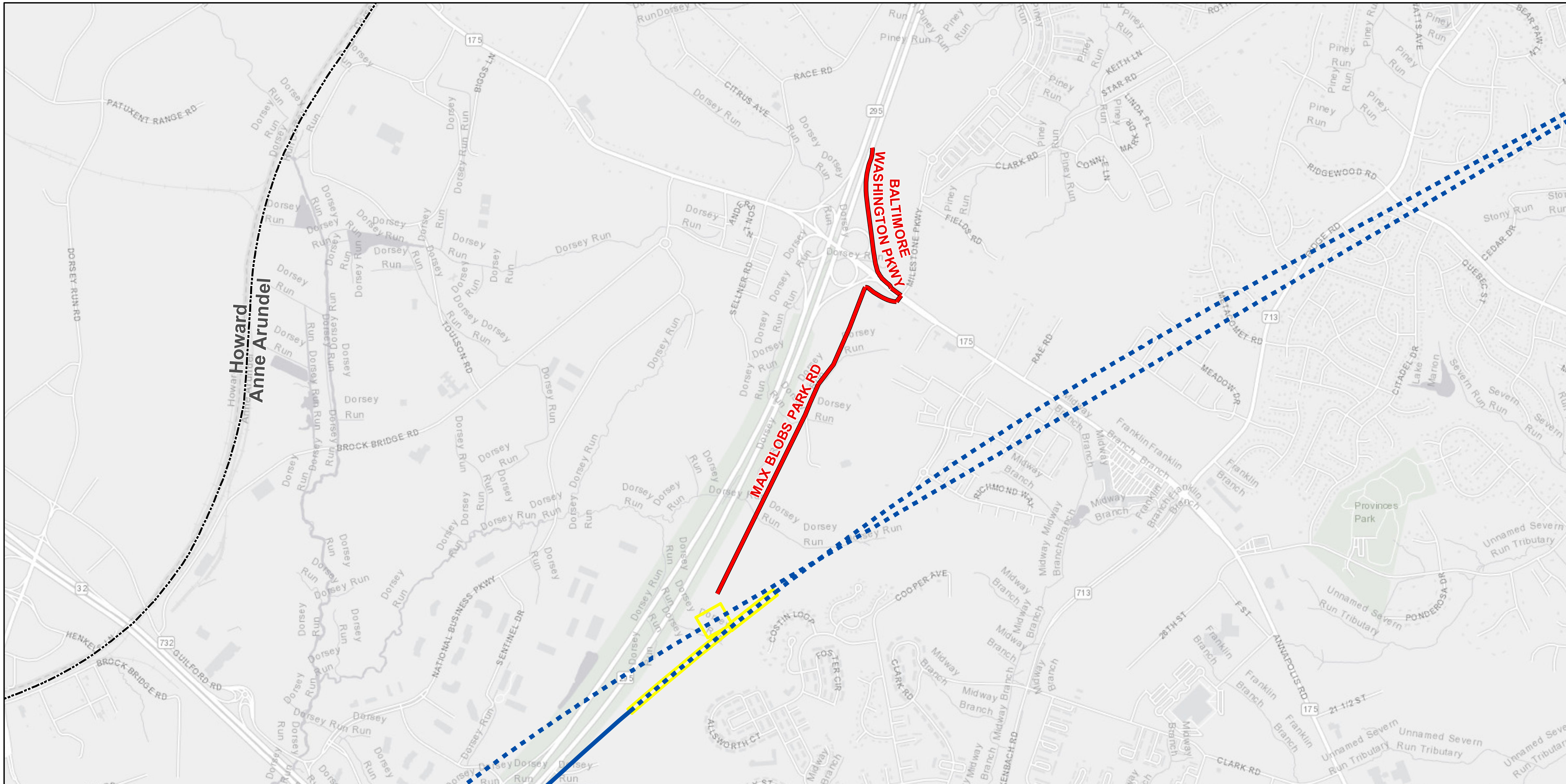
October 22, 2018

Harmans Vent Plant
Proposed Haul Route

BWRR — Louis Berger

0 — 0.25 — 0.5 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

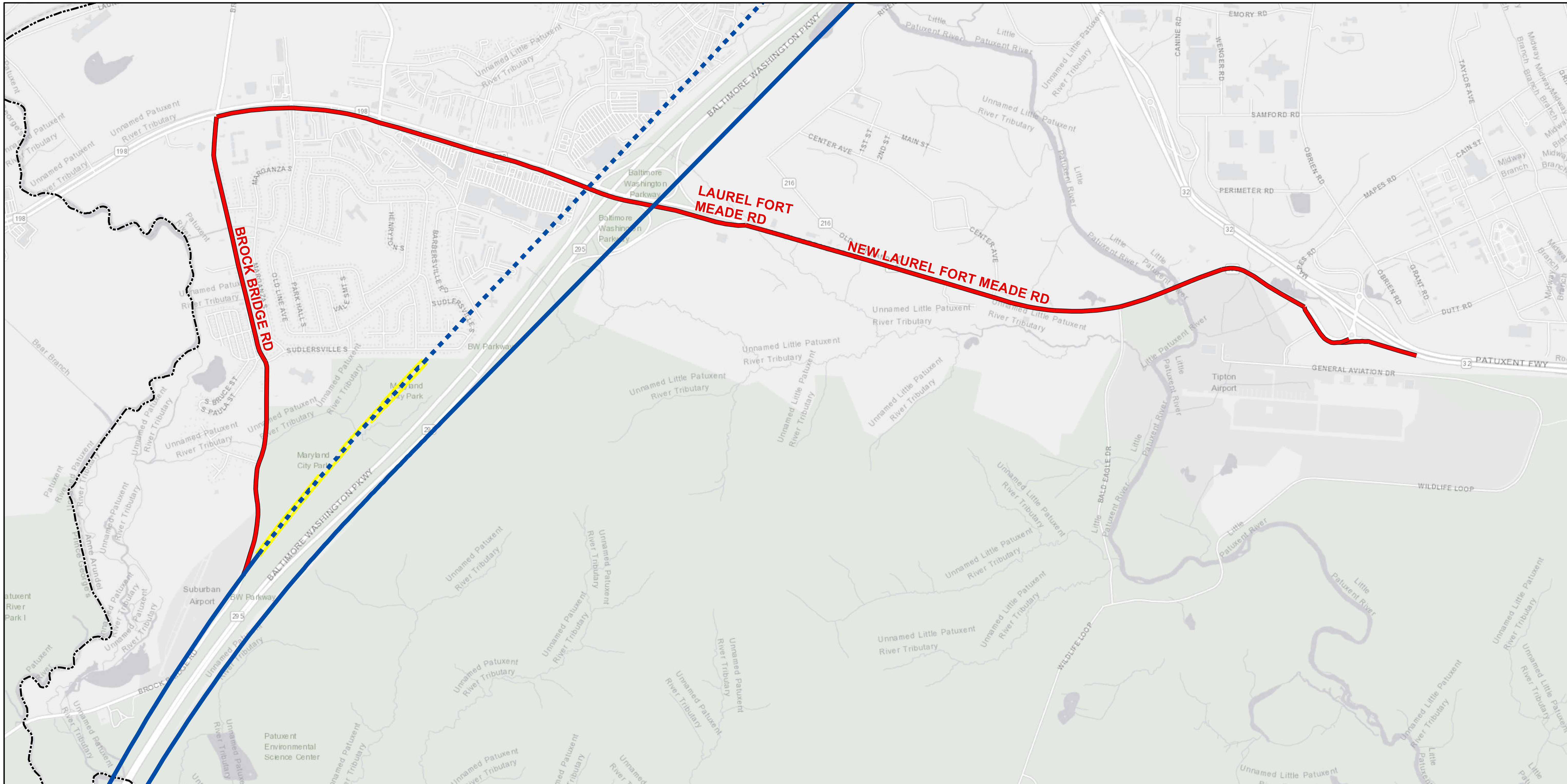
October 22, 2018

NSA Vent Plant/Portal Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 Miles

N

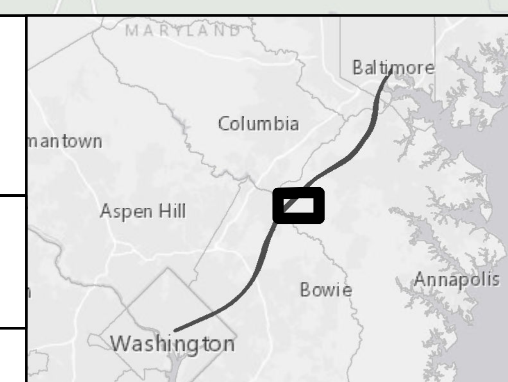


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

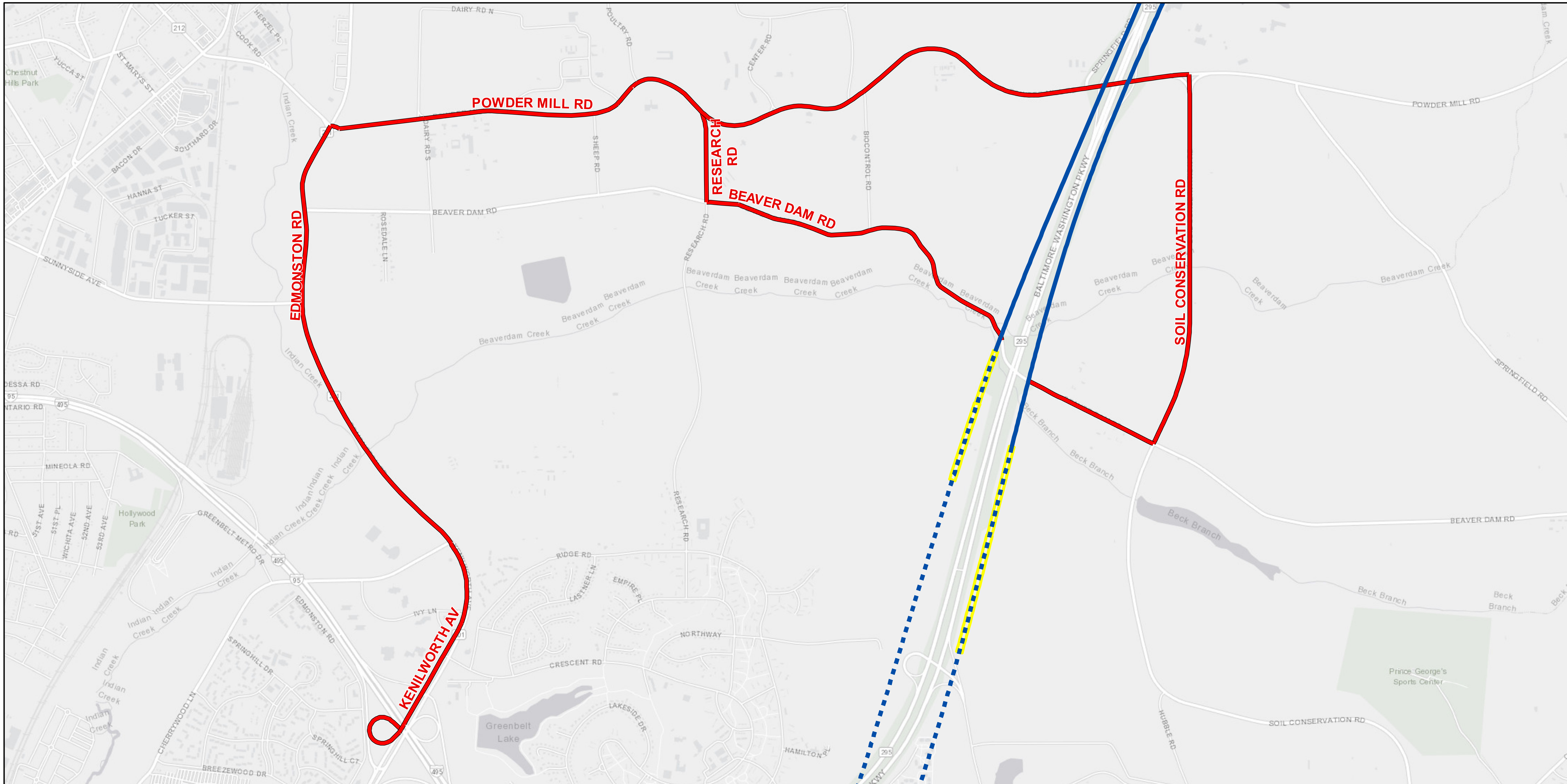
October 22, 2018



Maryland City Portal
Proposed Haul Route

BWRR
Louis Berger

0 0.25 0.5 0.75 Miles
N



Truck Route
Laydown Area
Elevated Structure
Deep Tunnel
County Boundary

Sources: ESRI (2017), BWRR (2017)

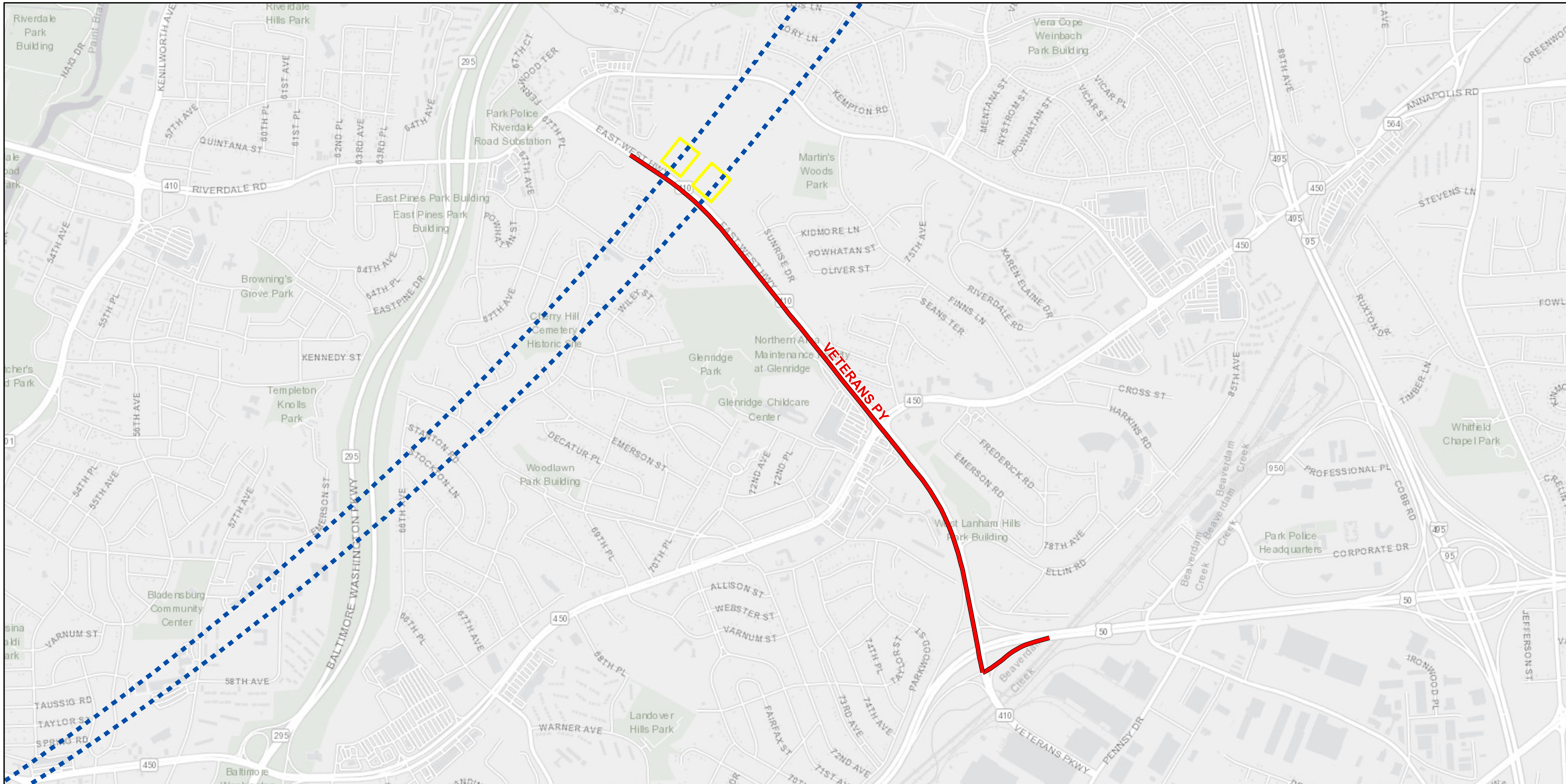
Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

BARC Portal
Proposed Haul Route

BWRR Louis Berger

0 0.25 0.5 0.75 Miles
N

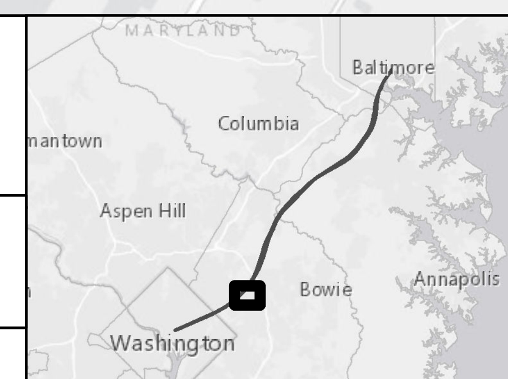


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

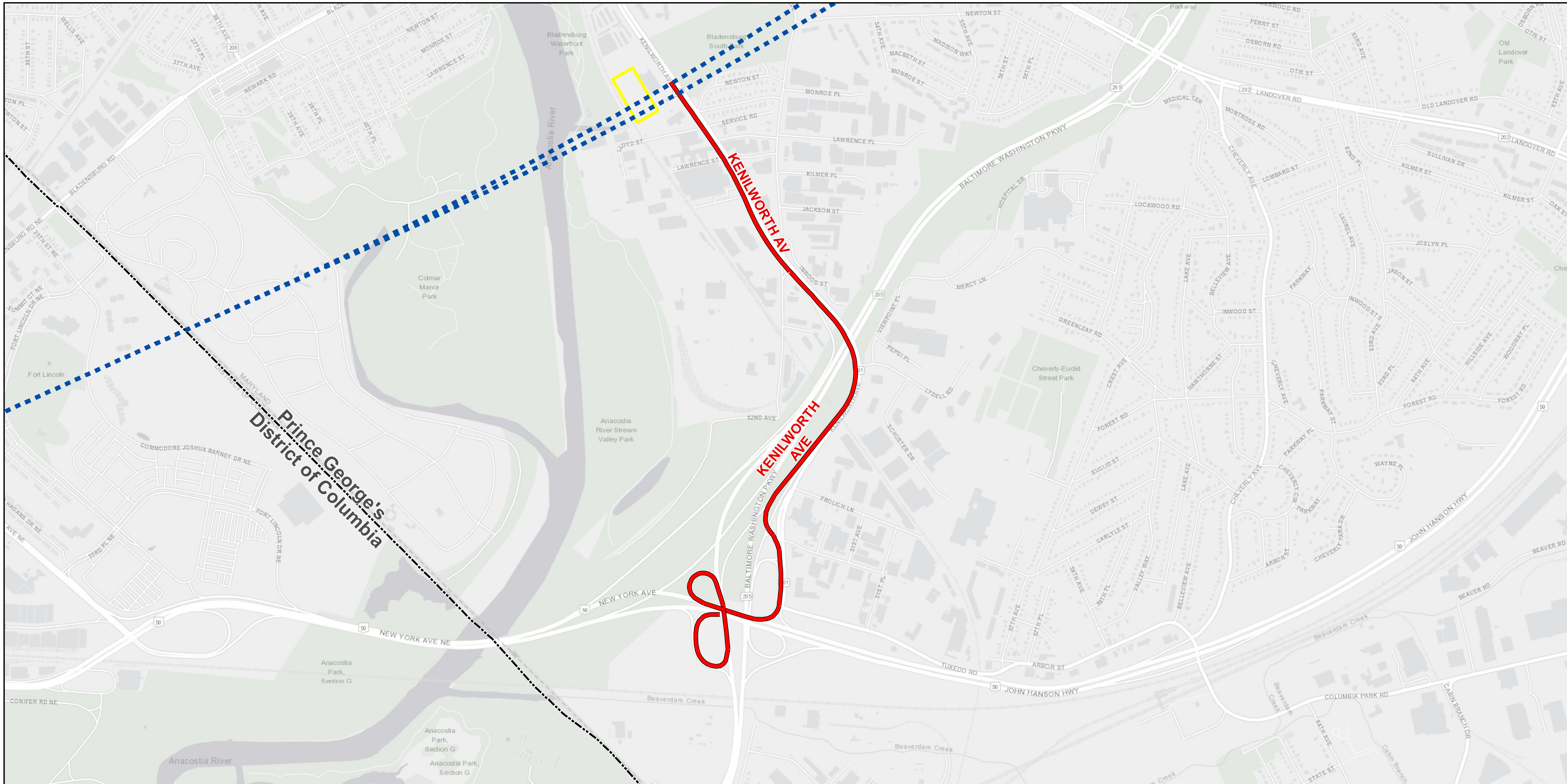


MD410 Vent Plant Proposed Haul Route

BWRR | Louis Berger

0 | 0.25 | 0.5 Miles

N



- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

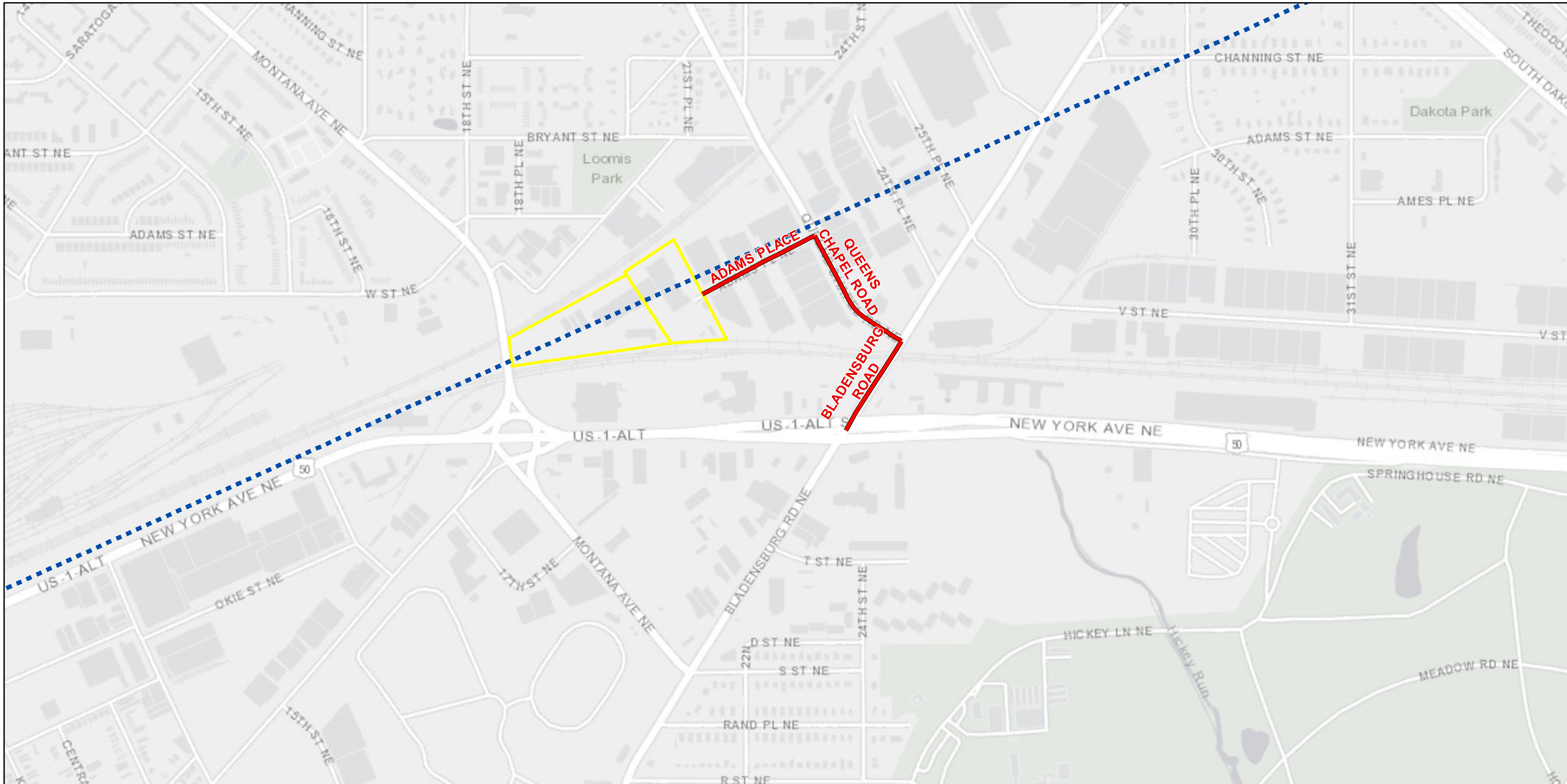
WSSC Vent Plant
Proposed Haul Route

BWRR
BALTIMORE-WASHINGTON RAPID RAIL

Louis Berger

0 0.25 Miles

N

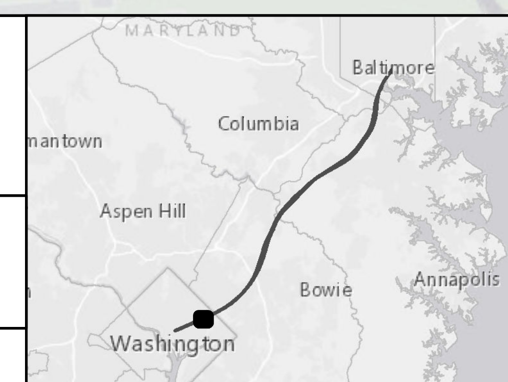


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018

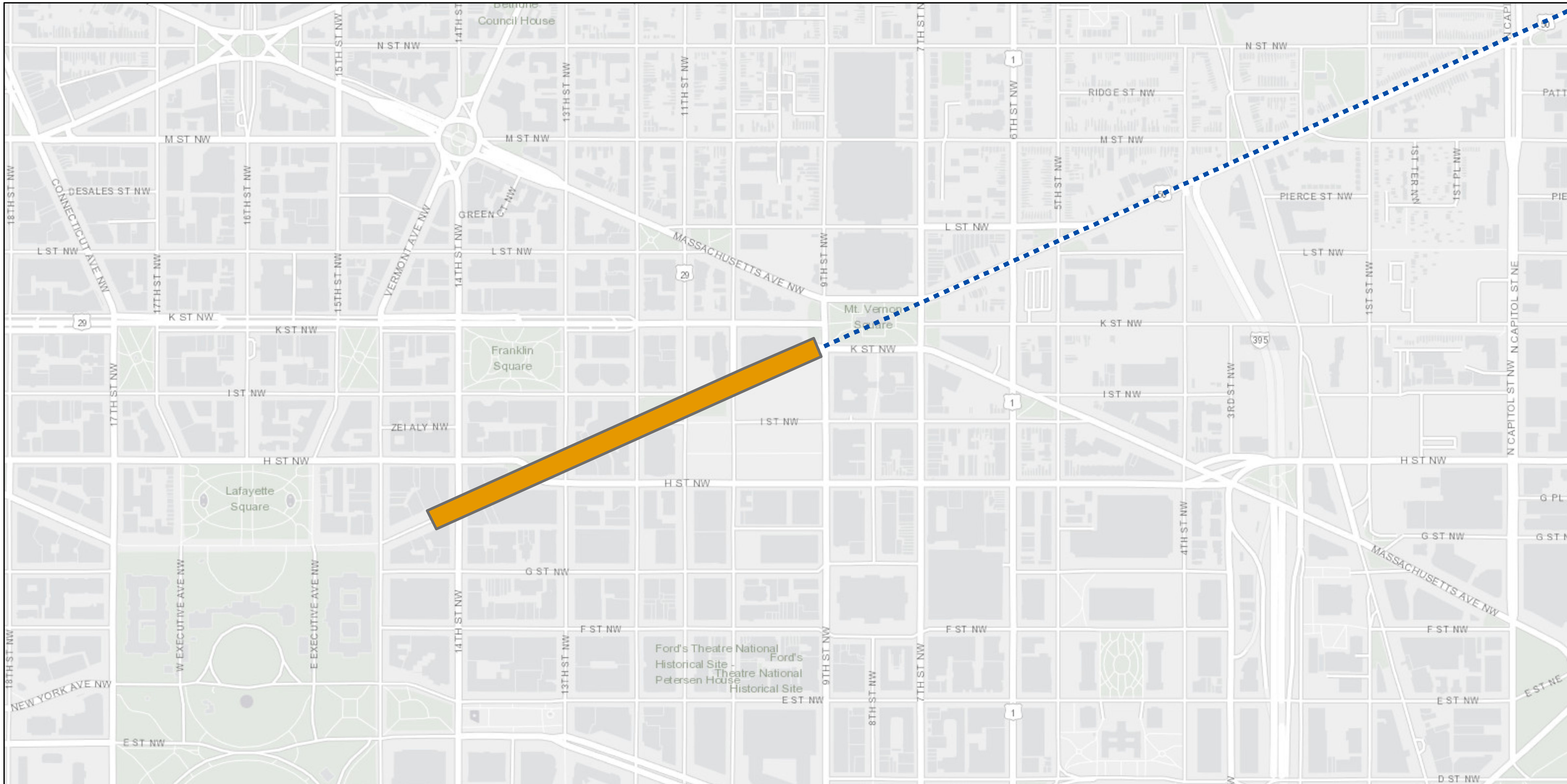


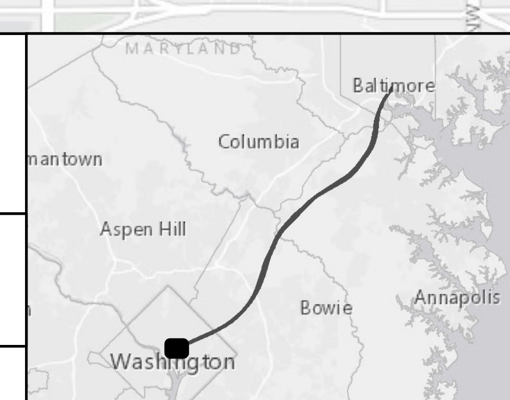
DC Surplus Vent Plant
Proposed Haul Route

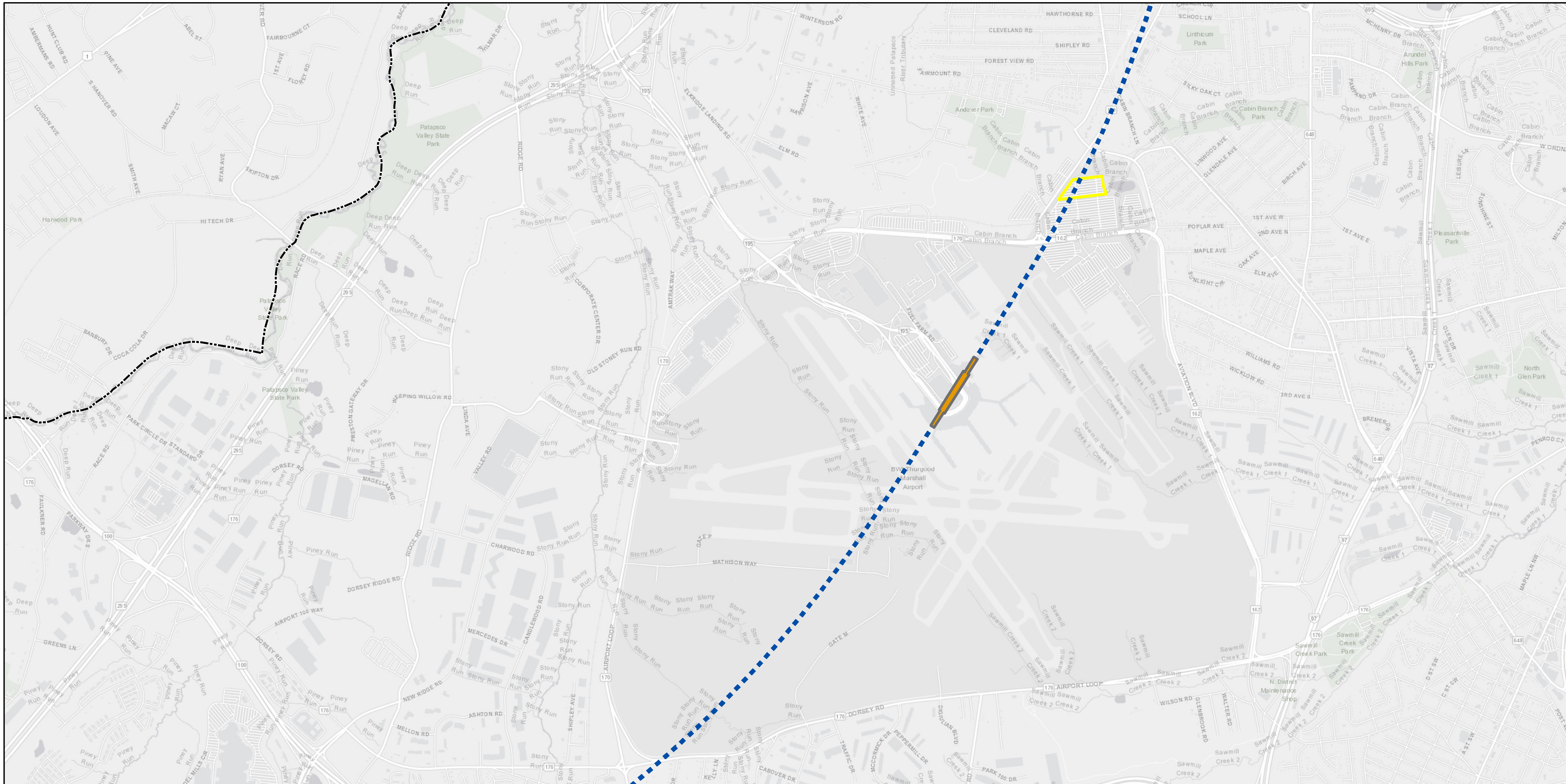
BWRR

Louis Berger

N



Truck Route Laydown Area Elevated Structure Deep Tunnel County Boundary	Sources: ESRI (2017), BWRR (2017) Coordinate System: NAD 1983 StatePlane MD (feet) Datum: North American 1983 October 22, 2018		**DC Station Proposed Haul Route** BWRR Louis Berger 0 0.25 Miles N

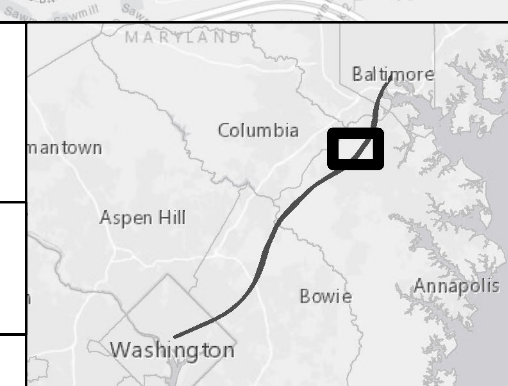


- Truck Route
- Laydown Area
- Elevated Structure
- Deep Tunnel
- County Boundary

Sources: ESRI (2017), BWRR (2017)

Coordinate System: NAD 1983 StatePlane MD (feet)
Datum: North American 1983

October 22, 2018



BWI Airport
Proposed Haul Route

BWRR
Louis Berger

0 0.25 0.5 0.75 1 Miles